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Canadian Stock Assessment Secretariat
Research Document 99/86

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Secrétariat canadien pour l'évaluation des stocks
Document de recherche 99/86

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Status of Atlantic Salmon (*Salmo salar* L.) in Gander River, Notre Dame Bay (SFA 4), Newfoundland, 1998

by

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ISSN 1480-4883
Ottawa, 1999

Canada

103-00123/

Abstract

The status of Atlantic salmon in Gander River in 1998 was determined using counts of small and large salmon from a counting fence located on the main stem just above head of tide, recreational fishery data, and biological characteristics information. Total returns of small salmon in 1998 increased by 77 % over the number recorded in 1997. Total returns in 1997 were the lowest since the implementation of the commercial salmon fishery moratorium in 1992. Run timing of small salmon in 1998 was the earliest of the moratorium years. Returns of large salmon in 1998 increased by 95% over 1997 and were the second highest of the moratorium years. The proportion of large salmon (0.163) in 1998 was also the second highest of the moratorium years. In contrast to 1997, when conservation egg requirement was not achieved (63%), requirement was exceeded in 1998 (113%). A study showed that counting fence operations did not affect the timing and availability of small salmon to anglers in Gander River. A number of stomachs of Atlantic cod (*Gadus morhua* L.) was examined in 1998 for evidence of predation on Atlantic salmon smolts. Sampling was conducted off Main Point, Gander Bay, during the period of out-migration of smolts. Of 125 cod stomachs examined, 2 (1.6%) contained smolts. Eight rock cod (*Gadus ogac* Richardson) were encountered, none of which showed evidence of preying on smolts.

Résumé

L'état du saumon de l'Atlantique de la rivière Gander en 1998 a été déterminé à partir du dénombrement des petits et grands saumons à une barrière de comptage située sur le cours principal de la rivière, tout juste en amont de la ligne de marée, des données de la pêche récréative et de renseignements sur les caractéristiques biologiques. Les remontées totales de petits saumons en 1998 ont augmenté de 77 % par rapport à la valeur de 1997, qui était la plus faible depuis l'imposition, du moratoire de la pêche commerciale du saumon en 1992. La période de remontée des petits saumons de 1998 est la plus hâtive de toute la durée du moratoire. Les remontées de grands saumons en 1998 ont été de 95 % supérieures à celles de 1997 et les deuxièmes plus élevées de toute la période du moratoire. La proportion de grands saumons (0,163) en 1998 était aussi la deuxième en importance depuis l'imposition du moratoire. Au contraire de 1997, où la ponte nécessaire à la conservation n'a pas été atteinte (63 %), les besoins ont été dépassés en 1998 (113 %). Une étude a montré que le fonctionnement de la barrière de comptage n'a pas influé sur le moment et la disponibilité des petits saumons pour les pêcheurs à la ligne de la rivière Gander. Un examen de plusieurs estomacs de morue de l'atlantique (*Gadus morhua* L.) a été effectué en 1998, pour connaître l'importance de la prédation des saumons de l'Atlantique. Les prélèvements ont été effectués au large de Maine Point, Gander Bay, pendant la période de migration vers la mer des saumoneaux. Des 125 estomacs examinés, 2 (1,6 %) contenaient des saumoneaux. Huit ogacs (*Gadus ogac* Richardson) ont aussi été capturés, mais aucun ne présentait d'indice de prédation des saumoneaux.

Introduction

The Gander River, with a drainage area of 6,398 km^2 (Porter *et al.* 1974), is the third largest in insular Newfoundland. The river is located in Salmon Fishing Area (SFA) 4 (Notre Dame Bay) (Fig. 1). In addition to being one of the most important Atlantic salmon angling rivers in insular Newfoundland, the river has historically supported a relatively large angler guiding and outfitting industry.

In response to concerns from angler groups that returns to the river were declining, the Department of Fisheries and Oceans in cooperation with the Gander Rod and Gun Club and the Gander Bay-Hamilton Sound Development Association, initiated a 3-year study to determine the status of the Gander River Atlantic salmon population in 1989. The results of this study (O'Connell and Ash MS 1992) showed that for the period 1989-91, Gander River received only 36-44% of its conservation egg requirement. As a result of the implementation of the commercial Atlantic salmon fishery moratorium in 1992 (see below), the project has continued in order to measure the impacts of this measure on adult returns and stock rebuilding.

In this paper, we examine the status of Atlantic salmon in Gander River in 1998, the seventh year of the commercial salmon fishery moratorium. Counts obtained from a counting fence are used in conjunction with recreational fishery data and biological characteristics data to calculate total river returns and egg deposition. Status of stock is evaluated against a conservation egg requirement (calculated in terms of fluvial and lacustrine habitats) derived for Gander River. Other information available in this document includes life-history characteristics of large salmon sampled in Gander River since 1978 and water temperature and water level data since 1989. The results of an examination of the impact of counting fence operations on the timing and availability of fish to anglers are presented. Arising out of the conclusions and recommendations of a workshop on possible causes of low returns of Atlantic salmon in 1997 (CSAS MS 1998), a study examining predation on Atlantic salmon smolts by cod was conducted in Gander Bay in 1998, the results of which are presented herein.

Management Measures, Past and Present

The introduction of the commercial Atlantic salmon fishery moratorium in insular Newfoundland in 1992 followed a major management plan introduced in 1984 (O'Connell *et al.* 1992a; May 1993), which was modified in 1990 and 1991 to include a commercial fishery quota in each SFA (O'Connell *et al.* MS 1992b). Elements of this management regime continued into the moratorium years. The moratorium placed on the Northern Cod Fishery in 1992, which should have eliminated by-catch of Atlantic salmon in cod fishing gear in SFAs 1-9, continued in 1998. There was a small index cod fishery in this area in September-October, which is outside the main migration period of June-early September for most Atlantic salmon destined for insular Newfoundland rivers.

A quota on the number of fish that could be retained in the recreational fishery was introduced in each SFA in 1992 and 1993. The quota was assigned for each SFA as a whole as opposed to individual river quotas. Only hook-and-release fishing was permitted after the quota was caught. Recreational fishery quotas were eliminated in 1994. In place of quotas, for insular Newfoundland, the season bag limit for retained small salmon was lowered from eight to six fish, three to be caught prior to July 31 and three after that date. Hook-and-release fishing only was permitted after the bag limit of three was reached in each time period. These measures remained in effect in 1995-97. As in previous years, retention of large salmon was not permitted in insular Newfoundland. Returns of small salmon to many rivers in insular Newfoundland in 1997 were substantially lower than expected (Dempson *et al.* Ms 1998; O'Connell *et al.* MS 1998a). As a result of this and uncertainties regarding levels of future returns, the management plan for 1998 was much more conservative than for previous years. The season bag limit for the retention of small salmon in 1998 was reduced to one, pending the results of an in-season review. As a result of the findings of the in-season review, anglers were allowed to additionally retain three small salmon from July 4 until the end of the angling season. There was a daily hook-and-release limit of two fish. Beginning on July 8, 1998, only the use of barbless hooks was permitted. All tributaries of Gander River except Northwest were closed to all angling for August 6-13 due to low water levels and high water temperatures; Northwest was closed for August 10-13. As was the case for the period 1995-97, there was a fall hook-and-release fishery in the main stem of Gander River below Gander Lake in 1998 (September 8-27).

Methods

Recreational fishery data and counts of adult salmon in 1998 were compared to two pre-salmon moratorium means (1984-89 and 1986-91). The 1984-89 mean corresponds to years under the major management changes in the commercial fishery in the Newfoundland Region, cited above. The 1986-91 mean incorporates the quota years of 1990 and 1991. The mix of management measures in effect during 1984-89 on the one hand and the imposition of commercial quotas in 1990 and 1991 on the other, should be kept in mind when making evaluations based on the 1986-91 mean. Recreational fishery data in 1998 were also compared to the moratorium mean for 1992-96 (see discussion of the License Stub Return System below) while counts of adult salmon were compared to the mean for 1992-97.

Adult salmon and smolt counting equipment

The location of the counting fence is shown in Fig. 1. Counts of adult Atlantic salmon were obtained with a positive image closed-circuit television (CCTV) system, which was operated in the boat passage in the counting fence, and by viewing VTR tapes. Visual counts were simultaneously conducted in the boat passage in order to categorise fish as small (< 63 cm) or large (≥63 cm) salmon. Counts were also obtained with a conventional adult trap installed in the counting fence. Counts for the Salmon Brook tributary (Fig. 1) were obtained with a conventional adult trap installed in the fishway. Counts of smolts were obtained with conventional traps installed in the counting fence. From 1989 to 1992 a single smolt trap was used, but beginning in 1993, a second

trap was added. These traps were installed for the purpose of releasing smolts migrating during the adult counting period; therefore counts are partial and account for a small portion of the total number of smolts leaving the river each year.

Recreational fishery data

Prior to 1997, catch and effort data for each river were collected by Department of Fisheries and Oceans (DFO) River Guardians and processed by DFO Science Branch staff, according to procedures outlined in Ash and O'Connell (1987). Rivers with counting facilities had information separated above and below the counting facilities. Data for 1997 and 1998 were derived from the License Stub Return System (see O'Connell *et al.* (MS 1998b) for a description of methodology). Data for 1998 are preliminary at this stage. It was not possible to apportion information above and below the counting fence with the License Stub. In 1997, catch and effort information was apportioned above and below the counting fence by applying the mean proportion for above and below for the period 1993-96 to the estimate for the entire river from the License Stub Return. In 1998, angling data for the area below the counting fence, were provided by River Guardians.

The License Stub Return System for collecting recreational fishery data represents a complete departure from the previous DFO River Guardian method. Details of a comparison of stub data with DFO River Guardian data, for rivers in insular Newfoundland for 1994-96, are provided in O'Connell *et al.* (MS 1998b). Overall, estimates of released small and large salmon from the stub were substantially higher than estimates from River Guardians, while the two methods were closer with respect to estimates of small salmon retained. This has to be kept in mind when comparing catches in 1997 and 1998 with previous years. There is evidence that effort expenditure was under-reported by the stub method and hence this information will not be used in the present document for both 1997 and 1998. Analyses are currently being carried out to adjust for under-reporting. The stub estimate for the number of large salmon released for 1997 is incomplete.

Biological characteristics

Biological characteristics information on adult Atlantic salmon in Gander River was obtained by sampling recreational catches. Information used in the calculation of egg deposition (mean weight and proportion female) for fish < 63 cm in length (small salmon) is shown in Table 1. Because the sample sizes for weight and proportion female in 1987, were small, the means for the pre-moratorium years 1984-91 were used to calculate egg deposition in that year. Similarly, the means for the moratorium period 1992-98 were used for 1998.

A mean weight of 3.13 kg and a proportion of female value of 0.77 (O'Connell *et al.* MS 1997) was used to calculate egg deposition for fish ≥ 63 cm in length (large salmon) for all years.

A mean relative fecundity value of 1,752 eggs/kg derived for Gander River (O'Connell *et al.* MS 1998c) was used for both small and large salmon in 1998.

Total river returns, spawning escapement, and egg deposition

Calculations were performed for small and large salmon separately. Total egg deposition was obtained by summing depositions for small and large salmon.

Total river returns

Total river returns (TRR) were calculated as follows:

$$TRR = RC_b + C + HRM_b \quad (1)$$

where,

RC_b = recreational catch below counting fence
C = count of fish at counting fence
HRM_b = hook-and-release mortalities (10% of hook-and-release fish) below counting fence

A partial count of small and large salmon was obtained at the counting fence in 1992. High water levels caused a delay in counting fence installation until July 1. During the period of delay, fish were counted upriver at the Salmon Brook fishway and also there were some angling catches. The numbers of small and large salmon entering Gander River prior to July 1 in 1989 and 1990 represented on average 4.8% and 7.5% of the total counts. The total counts of small and large salmon for 1992 were adjusted using these percentages and daily counts estimated as the the product of the average proportion of total count (for 1989-90) on a daily basis and estimated total count. Information for 1991 was not used because in that year timing of adult migration was later than in 1989 and 1990 (O'Connell and Ash MS 1992). A similar approach was used to adjust the counts of small and large salmon at the Salmon Brook fishway in 1990. In that year, counts were not obtained during the last two weeks of the run prior to the cessation of counting operations because of extremely low water conditions. The average percentage of small and large salmon counted at the fishway up to August 16 during the period 1984-91 (exclusive of 1987) was 95 and 90.

Spawning escapement

Spawning escapement (SE) was calculated as follows:

$$SE = TRR - RC_t - HRM_t \quad (2)$$

where,

RC_t = total recreational catch
HRM_t = total hook-and-release mortalities (10% of hook-and-release fish)

Egg deposition

Egg deposition (ED) was calculated as follows:

$$ED = SE \times PF \times RF \times MW \quad (3)$$

where,

SE = number of spawners
PF = proportion of females
RF = relative fecundity (No. eggs/kg)
MW = mean weight of females

The phenomenon of atresia occurs in Atlantic salmon in insular Newfoundland (O'Connell and Dempson MS 1997). Since the egg deposition calculations above were based on eggs in early stages of development, they should be regarded as potential egg depositions.

Conservation egg deposition and spawner requirements

Conservation egg deposition and spawner requirements for Gander River, were developed by O'Connell and Dempson (MS 1991). The egg requirement for classical fluvial parr rearing habitat (Elson 1957) was 240 eggs/100 m^2 (Elson 1975); the requirement for lacustrine habitat was 368 eggs/ha (O'Connell and Dempson 1995). **It should be noted that Gander Lake was not included in the calculation of the egg deposition requirement.**

Accessible rearing habitat and conservation egg and spawner requirements in terms of fluvial and lacustrine habitats were as follows:

	Lacustrine	Fluvial	Total
Accessible habitat	21488 ha	159560 units	
Eggs (No. x 10^6)	7.917	38.294	46.211
Small salmon (No.)	3739	18089	21828

The adult conservation spawning requirement was calculated in terms of small salmon only. Egg deposition from large salmon was considered as a buffer.

Net marks

Since 1994, adult salmon entering the adult trap installed in the counting fence have been examined for the incidence of net marks.

Run timing through counting fence in relation to angling catches

Median day of the year recreational retained catches of small salmon for a period of five years prior to the installation of the counting fence (1984-88) were compared with those during counting fence operations for the years 1989-96 (1996 was the last year of daily catches as provided by River Guardians). The SFA quota years of 1992 and 1993 were excluded from this analysis because in each of these years there was only a partial season for retention of catch

(O'Connell and Ash MS 1993, MS 1994). Statistical comparisons between the pre-counting fence period and the counting fence period were made using the General Linear Models Procedure of SAS (SAS Institute 1985). The analysis was performed on rank transformed data (Conover 1980; Conover and Iman 1981) using the Rank Procedure of SAS.

Environmental data

Water temperatures were measured at the counting fence with a Hugrun Seamon digital thermograph. Water levels were measured near the counting fence each year over a permanent benchmark installed in the river.

Predation on smolts

Sampling of cod was conducted at various locations in the vicinity of Main Point, Gander Bay, approximately 12.5 km from the mouth of Gander River (Fig. 1). A single polyfilament nylon gillnet (length = 91.44 m; depth = 5.49 m; stretched mesh size = 13.97 cm) was hauled and reset in the morning of each day from June 11 to July 4. Stomach analysis and measurements of length and weight were carried out on fresh specimens according to protocols used by Gadoids Section, Groundfish Division, Science Branch, DFO, St. John's.

Results

Recreational fishery

Catch and effort data are presented in Appendix 1. Catches for all years prior to 1992 represent retained catch for the entire angling season. Total catch for 1998 (retained plus released fish) is compared to years prior to 1992 and 1992-96 (1997 data were derived from the License Stub System, as seen above, and hence were not included in means). There was no estimate of released fish during the period of retention of catch in 1992, which could impact on comparisons. The total number of fish retained in 1998 is also shown. Calculation of catch per unit of effort (CPUE) in terms of retained fish only was not possible since effort figures apply to both retained and released fish collectively. For reasons pointed out above, effort and CPUE information are not available for 1997 and 1998.

The total catch of small salmon (retained plus released fish) in 1998 increased over that of 1997 (67%) and the 1984-89 (62%), 1986-91 (121%), and 1992-96 (24%) means. The number of small salmon retained in 1998 increased over 1997 (80%) and the 1986-91 mean (12%), decreased from the 1984-89 mean (18%), and was similar to the 1992-96 mean (-7%). The number of small salmon released in 1998 increased over 1997 (64%) and the 1992-96 mean (76%); the number of large salmon released increased by 13% over the partial estimate for 1997 and was the highest on record.

In 1998, 26 small salmon and 2 large salmon (preliminary numbers) were released in the fall hook-and-release fishery. Thirty-eight small and 3 large salmon were released in 1997; effort expenditure was 100 rod days. In 1996, 128 small and 17 large salmon were released; effort expended was 231 rod days. In 1995, 30 small and 9 large salmon were released with an effort expenditure of 158 rod days.

Counts at counting fence and fishway

Adults

Counts of small and large salmon for the Gander River counting fence for the period 1989-98 are shown in Table 2 and Fig. 2. The count of small salmon in 1998 increased over 1997 (79%) and the pre-moratorium mean for 1989-91 (159%) and was similar to the moratorium mean, 1992-97 (-5%). The count of large salmon in 1998 was the highest since 1992, increasing over 1997 (94%) and the 1989-91 (563%) and 1992-97 (87%) means. The peak daily count of small salmon in 1998 occurred during the last week of June compared to early July in 1997; the 1998 peak was also a few says earlier than that of 1996, which up to that year was the earliest run timing of the moratorium years (Fig. 3). The distribution of daily counts of small salmon in 1997 was relatively flat compared to the other years since 1992. The peak count for large salmon in 1998 occurred during the third week of July as opposed to early August in 1997; in contrast to the other years, most returns were concentrated in August in 1997. The median daily count of small salmon in 1998 occurred in early July (the earliest of the moratorium years), compared to around the third week of July in 1997, and about a week earlier than in 1996 (Fig. 4). The median for large salmon in 1998 occurred during the third week of July as opposed to early August in 1997 (the latest of the moratorium years). The peak for large salmon in 1998 occurred approximately 16 days later than that of small salmon. The number of days between the medians for small and large salmon was highest in 1998 and 1997, in that order, while in 1992 and 1993, the medians coincided.

Counts of small and large salmon for the fishway located in Salmon Brook tributary for the period 1974-98 are shown in Table 3 and Fig. 2. The count of small salmon in 1998 increased over 1997 and the 1984-89, 1986-91, and 1992-97 means (178, 20, 80, and 16%, respectively). The count of large salmon in 1998 was the highest on record, increasing over 1997 and the means (18, 536, 971, 35%, respectively).

Smolts

Numbers of smolts counted at the counting fence each year since 1989 are shown in Table 2. Coincident with the installation of the second trap in 1992, there was a large increase in the total number of smolts counted. The number of smolts counted each year depended on when the counting fence was installed, which in turn depended on water levels. By the time the counting fence was installed, smolt runs usually had already been in progress to varying degrees, subject to variations in annual run timing. Therefore, it is felt that these counts have limited value as annual indicators of the total numbers of smolts leaving the river. With these constraints in mind, annual run timing of smolts through the traps is presented in Fig. 5. Latest median run timing (day of the

year) occurred in 1992 while the earliest was in 1995. Timing for 1998 was the third earliest. While the date when first smolts were encountered each year was a function of when the fence was installed, the timeframe of adult counting permitted the determination of when the last smolts left the river for the season. Small numbers of smolts continued to le e the river well into August in six of the ten years of counts, and in 1991, a few smolts were counted on September 3. The earliest date for observing the last smolts was July 17, 1996.

Total river returns, spawning escapement, and percentage of conservation requirement achieved

Total river returns, spawning escapement, potential egg deposition, and percentage of conservation requirement achieved for Gander River in 1989-98 are presented in Table 4. Total returns of small salmon in 1998 increased by 77% over 1997 and decreased by 6% from the mean for moratorium years 1992-97; with 1997 excluded from the mean, the decline was 14%. The percentage of conservation egg requirement achieved for 1989-97 is also shown in Fig. 6. Less than 50% of conservation requirement was achieved for small salmon in terms of egg deposition prior to the moratorium. Conservation egg requirement was exceeded in 1998, which is in contrast to the situation for 1997, when the lowest egg deposition of the moratorium years was recorded. During the moratorium years, in addition to 1998, conservation egg requirement was achieved in 1992, 1993, and 1996, although the years 1994 and 1995 were close to requirement at 91 and 95%. The conservation requirement for small salmon was met only in 1993. The highest proportionate contribution to total egg deposition by large salmon occurred in 1992 followed by 1998 and 1997, in that order.

Net marks

The numbers of small and large salmon examined for net marks and the numbers and percentages bearing net marks in 1994-98 were as follows:

Year	Small salmon (No.)			Large salmon (No.)			Total (No.)		
	Examined	Marked	%	Examined	Marked	%	Examined	Marked	%
1994	223	36	16.1	10	1	10.0	233	37	15.9
1995	233	16	6.9	13	6	46.1	246	22	8.9
1996	407	52	12.8	34	2	5.9	441	54	12.2
1997	162	27	16.7	33	4	12.1	195	31	15.9
1998							2064	59	2.9

The highest percentage of small salmon with net marks occurred in 1997, while for large salmon it occurred in 1995. For small and large salmon combined (total), the incidence in 1997 was the same as in 1994, the highest of the five years, while that of 1998 was the lowest.

Run timing through counting fence in relation to angling catches

Timing (day of the year) of retained recreational catches of small salmon for Gander River for the years 1984-96 is shown in Fig. 7. Excluding the years 1992 and 1993 from the analysis, for reasons explained above, there was no significant difference in timing of median catch ($F = 0.01$; $P = 0.9320$) between the period prior to counting fence installation (1984-88) and the period of fence operations (1989-96). With 1992 and 1993 excluded, there was a significant positive relationship between the time of median count of small salmon through the counting fence and time of median retained catch of small salmon (Fig. 8). Also catch per unit of effort (CPUE) for the period 1989-96 was positively and significantly related to total returns of small salmon (Fig. 9). Overall, these results suggest that the counting fence did not impact on timing of angling catches, fish were exploited as they entered the river, and angling success also reflected abundance.

Life-history of large salmon

The numbers and percentages of the various life-history groupings comprising the large salmon component of returns to Gander River since 1978 are presented by individual year and for years combined in Table 5. Overall, the dominant group was consecutive spawning grilse followed by alternate spawning grilse, virgin grilse, and virgin large salmon (a minor component). These groups are broken out in terms of freshwater residence (smolt age), virgin sea life, and spawning history, as denoted by notation, for all years combined, in Table 6. With respect to the notation, the number to the left of the first period is the smolt age, and everything to the right is sea life. The first number to the right of the first period is the virgin sea life while SM denotes a spawning mark. Among consecutive spawners, the number of spawnings ranged from one to five. Some of the alternate spawners later adopted a consecutive spawning strategy (3.1.SM.1.**SM.SM**; 4.1.SM.1.**SM.SM**). The virgins were 2-sea-winter fish.

Environmental conditions

Maximum and minimum daily water temperatures (°C) and daily mean water levels (cm) recorded during counting fence operations for the period 1989-91 are shown in Appendices 2 and 3 and Figs. 10 and 11. Maximum daily water temperatures in 1998 exceeded 20 °C for much of the period beginning in early July until around the third week in August; the highest temperature encountered was 24.6 °C, recorded on August 10. Minimum temperatures during this period generally dipped below 20 °C. Water levels were generally low, especially from early July onwards; the lowest mean value was encountered on August 12.

Predation on smolts

The results of stomach analysis for Atlantic cod (*Gadus morhua* L.) and rock cod (*Gadus ogac* Richardson) are shown in Table 7. Atlantic herring (*Clupea harengus harengus* L.) was the principal component of the diet of both Atlantic cod and rock cod. Smolts were found in two Atlantic cod stomachs; one stomach contained three smolts (from a cod with a total length of 63 cm caught on June 17) and the other had four smolts (from a cod with a total length of 54 cm caught

on July 23). No smolts were found in the relatively small sample of rock cod stomachs. The length distribution of Atlantic cod (N = 125) is shown in Fig. 12. Rock cod (N = 8) ranged in total length from 49 to 60 cm (mean = 54.8; SD = 3.89). Smolts were leaving the river during the entire period of cod sampling (Fig. 13).

Discussion

Total returns of small salmon to Gander River in 1998 showed a marked improvement over those of 1997. Beginning in 1997, it was anticipated that there would be a substantial increase returns of small salmon, resulting from the greatly increased egg deposition levels starting with the commercial salmon fishery moratorium in 1992 (Table 4). The lower than expected returns for Gander River in 1997 was consistent with observations for other rivers with counting facilities in insular Newfoundland, particularly on the Northern Peninsula and northeast and east coasts. For detailed analyses examining possible reasons for the overall low returns of small salmon in insular Newfoundland in 1997, which includes information and discussion for Gander River, see Dempson *et al.* (MS 1998) and O'Connell *et al.* (MS 1998a). While total returns of small salmon for Gander River in 1998 improved over numbers recorded in 1997, they remained average for the moratorium period 1992-97 and slightly below average with 1997 excluded. It is unfortunate that smolt data cannot be used as indicative of smolt production from Gander River, for reasons discussed above. For other rivers distributed throughout insular Newfoundland, where there are complete smolt and adult counts, there are indications that continuing low smolt-adult (sea) survival (O'Connell *et al.* MS 1999) may have played a major role in the level of small salmon in 1998.

Conservation requirement in terms of small salmon was met on only one occasion during the moratorium years. It is quite evident from Table 6 that large salmon emanating from many spawnings, as exhibited by their smolt ages and highly variable spawning histories, contribute to egg deposition in any given year. During a period of low survival of virgin fish such as appears to be the case in recent years, the value of the contribution of large salmon in achieving conservation egg deposition requirement cannot be underestimated.

The incidence of net marks in 1998 was the lowest of the moratorium years. The occurrence of net marks was likely the result of encounters with illegal and legal fishing gear in coastal waters and illegal gear in the river below the counting fence. It is not possible to accurately estimate the extent of such removals. Therefore total returns considered in the context of being equivalent to total production during the moratorium have to be regarded as minimum values.

Cautions associated with the parameter values used to calculate the conservation egg requirement have been discussed previously by O'Connell and Dempson (1995) and will not be dealt with here.

There was no evidence that counting fence operations interfered with the timing and availability of fish to anglers. The configuration of the counting fence and placement of traps have been continually altered over the years in an effort to minimise the impact of operations on the run

timing of adults. Experimentation with and utilisation of various electronic and closed-circuit television fish counting and measuring systems have been ongoing on the project since 1991. All these measures have culminated in a very efficient and accurate system of passing fish, resulting in minimal hold-up or delay in migration below the counting fence. Evidence suggests, that complaints from anglers regarding the negative influence of the counting fence on angling success, are based more on perception than on fact.

The low incidence of predation on smolts by Atlantic cod is consistent with results obtained in a similar study conducted in 1998 for Campbellton River, also located in SFA 4 (Downton and Reddin MS 1999). Predation on wild and hatchery-reared smolts by Atlantic cod has also been demonstrated for two rivers in Norway (Hvidsten and Møkkelgjerd 1987; Hvidsten and Lund 1988). Predation was described as heavy, smolts were the dominant food items, and cod were thought to assemble in the estuaries to forage on smolt runs. In the present study, smolts were not the dominant food items and in fact constituted only a minor component of the total diet of cod. The Norwegian studies had estimates of the population sizes of cod preying on smolts and hence it was possible to estimate smolt mortality due to this factor. Obviously, in order to determine the role of predation by cod in the possible recent low sea survival of Gander River smolts, population estimates or some index of population size of cod in Gander Bay and possibly farther out into Notre Dame Bay are required, as well as estimates of smolt production from Gander River.

Acknowledgements

The operation of the counting fence in Gander River in 1997 was carried out as a Joint Project between DFO and the Gander River Management Association.

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Table 1. Biological characteristics data for female small salmon and with sexes combined plus unsexed fish by year and for pre-moratorium (1984-91) and moratorium (1992-98) periods for Gander River (SFA 4), Newfoundland. WW = whole weight (kg); FL = fork length (cm); RS = repeat spawning grilse.

	Sexes combined plus unsexed									Females						%	
Year	$\bar{X}$ WW	SD	N	$\bar{X}$ FL	SD	N	% RS year of return	% RS smolt class	N	$\bar{X}$ WW	SD	N	$\bar{X}$ FL	SD	N	Female	N
1984	1.54	0.35	109	51.3	3.80	109	2.8	-	3	1.54	0.39	71	51.1	3.89	71	65	71
1985	1.62	0.33	111	51.0	3.66	113	1.8	1.9	2	1.63	0.34	82	51.0	3.59	84	74	84
1986	1.61	0.35	51	52.1	3.27	51	11.8	5.3	6	1.76	0.30	32	53.1	2.90	32	82	32
1987	1.49	0.37	19	50.6	3.50	19	0.0	0.0	0	1.47	0.40	15	49.8	3.45	15	79	15
1988	1.63	0.33	40	52.6	3.56	40	5.0	9.5	2	1.61	0.33	33	52.4	3.74	33	83	33
1989	1.60	0.38	187	52.8	4.11	186	9.4	30.9	17	1.66	0.39	89	53.5	4.13	88	83	89
1990	1.80	0.47	245	53.7	4.07	245	5.4	7.4	13	1.84	0.48	170	54.0	4.24	170	73	170
1991	1.70	0.46	142	52.8	3.93	141	0.7	0.4	1	1.66	0.47	110	52.3	3.90	109	85	110
1992	1.80	0.44	149	54.3	3.80	172	0.0	0.0	0	1.78	0.44	87	54.6	4.02	108	65	109
1993	1.86	0.41	144	55.1	3.98	145	5.6	4.5	8	1.85	0.39	73	55.0	3.28	73	70	73
1994	1.75	0.49	196	53.6	4.18	196	7.5	8.8	13	1.83	0.46	101	54.1	4.25	101	73	101
1995	1.73	0.51	76	52.5	4.73	73	2.7	1.2	2	1.72	0.51	48	52.1	5.13	46	66	48
1996	1.95	0.57	105	54.6	4.40	120	5.9	8.8	7	1.95	0.56	68	54.6	4.35	71	70	71
1997	1.65	0.44	27	54.2	4.67	212	27.0	32.7	54	1.68	0.48	17	54.4	3.94	20	72	20
1998	1.83	0.44	20	53.3	4.40	217	2.5	3.3	5	1.87	0.47	15	54.8	5.15	15	83	15
Pre-moratorium 1984-91	1.66	0.42	904	52.5	4.01	904	4.9	7.9	44	1.69	0.43	602	52.6	4.10	602	77	604
Moratorium 1992-98	1.81	0.47	717	54.0	4.34	1135	8.2	8.5	89	1.83	0.47	409	54.3	4.23	434	69	437

Table 2. Counts of Atlantic salmon smolts and adults at the Gander River counting fence, 1989-98. Adjusted counts are bold and in italics.

Year	Smolts	Adults	
		Small	Large
1989	12556	7743	473
1990	19777	7520	508
1991	12973	6445	670
1992	11104	***18179***	***4162***
1993	29913	25905	1734
1994	49109	18080	1072
1995	59370	22002	1121
1996	99149	23665	1753
1997	35873	10474	1883
1998	6860	18742	3649
$\bar{X}$ 86-91		7236	550
95% LCL		5512	289
95% UCL		8960	811
N		3	3
$\bar{X}$ 92-97		19718	1954
95% LCL		13977	763
95% UCL		25458	3145
N		6	6

Table 3. Counts of small and large salmon at Salmon Brook fishway, 1974-98. Partial counts are in parentheses and are not included in the means. Adjusted counts are bold and in italics.

Year	Small salmon	Large salmon
1974	857	9
1975		
1976		
1977		
1978	755	52
1979	(404)	(6)
1980	997	15
1981	2459	33
1982	1425	18
1983	978	12
1984	1081	38
1985	1663	26
1986	1064	12
1987	493	9
1988	1562	24
1989	596	24
1990	***345***	***8***
1991	245	2
1992	1168	101
1993	1560	87
1994	968	83
1995	1600	125
1996	946	112
1997	465	119
1998	1295	141
$\bar{X}$ 84-89	1076.5	22.2
95% LCL	572.9	11.2
95% UCL	1580.1	33.2
N	6	6
$\bar{X}$ 86-91	717.5	13.2
95% LCL	190.5	3.7
95% UCL	1244.5	22.6
N	6	6
$\bar{X}$ 92-97	1117.8	104.5
95% LCL	670.4	86.5
95% UCL	1565.3	122.5
N	6	6

Table 4. Total river returns, spawning escapements, and percentage of conservation requirement achieved in terms of small salmon and eggs for Gander River, 1989-98.

Year	Total returns (No.)		Prop.	Spawning escapement (No.)		Egg deposition (Millions)		% cons. req. achieved		Eggs per
	Small	Large	Large	Small	Large	Small	Large	Small	Eggs	100 sq. m
1989	7743	473	0.058	6570	473	18.005	2.264	30.1	44	127
1990	7740	508	0.062	6585	508	15.381	2.126	30.2	38	110
1991	6745	670	0.090	5565	670	13.757	2.825	25.5	36	104
1992	18179	4162	0.186	17143	4162	36.317	18.343	78.5	118	343
1993	26205	1734	0.062	24739	1725	52.477	6.800	113.3	128	372
1994	18273	1072	0.055	16106	1068	37.697	4.504	73.8	91	264
1995	22266	1121	0.048	19606	1114	38.994	4.696	89.8	95	274
1996	23946	1753	0.068	20822	1746	49.796	7.362	95.4	124	358
1997	10599	1883	0.151	9437	1864	20.877	7.861	43.2	62	180
1998*	18805	3649	0.163	16731	3628	37.013	15.298	76.6	113	328

*Preliminary

Table 5. Number and percentage (in parentheses) of life-history groups in the large salmon category (>= 63 cm fork length) for Gander River, 1978-98.

Year	VG	CSG	ASG	VLS
1978			1(100.0)	
1980	2(66.7)	1(33.3)		
1981		1(100.0)		
1982	2(40.0)	2(40.0)		1(20.0)
1988	1(100.0)			
1989		2(100.0)		
1990	5(100.0)			
1991	1(100.0)			
1993		5(71.4)	2(28.6)	
1994	5(71.4)	1(14.3)	1(14.3)	
1995			9(90.0)	1(10.0)
1996		1(100.0)		
1997	1(2.6)	32(84.2)	5(13.2)	
1998	1(8.3)	7(58.3)	3(25.0)	1(8.3)
Total	18(19.2)	52(55.3)	21(22.3)	3(3.2)

VG = virgin grilse; CSG = consecutive spawning grilse;
ASG = alternate spawning grilse; VLS = virgin large salmon

Table 6. Life-history groups by percentage notation for large salmon (>= 63 cm) for Gander River and corresponding length and weight information. Data are for years combined, 1978-98.

Life-history group	Notation	Notation		Fork length (cm)					Whole weight (kg)				
		N	Percent	Min.	Max.	Mean	SD	N	Min.	Max.	Mean	SD	N
Virgin grilse	3.1	4	22.2	63.0	64.0	63.6	4.20	4	2.80	3.30	3.10	0.26	3
	4.1	14	77.8	63.0	65.0	63.6	7.81	14	2.30	3.50	2.83	0.34	14
Consecutive spawning grilse	3.1.SM	3	5.8	63.0	63.5	63.2	2.87	3	2.15	2.90	2.52	0.37	3
	3.1.SM.SM	5	9.6	63.0	82.6	69.5	79.40	5	3.10	7.71	5.30	2.31	3
	3.1.SM.SM.SM	2	3.8	65.5	69.0	67.3	24.75	2					
	4.1.SM	6	11.5	63.0	68.0	65.0	22.11	6	2.38	4.50	3.20	0.81	5
	4.1.SM.SM	17	32.7	63.0	78.1	67.7	46.90	17	2.40	3.00	2.70	0.30	3
	4.1.SM.SM.SM	11	21.2	64.4	82.8	71.0	59.24	11					
	4.1.SM.SM.SM.SM	1	1.9			74.0		1					
	4.1.SM.SM.SM.SM.SM	1	1.9			73.5		1					
	5.1.SM	1	1.9			66.7		1					
	5.1.SM.SM	3	5.8	63.1	71.5	66.2	46.10	3					
	5.1.SM.SM.SM	1	1.9			68.0		1					
	5.1.SM.SM.SM.SM	1	1.9			70.8		1					
Alternate spawning grilse	2.1.SM.1.SM	1	4.8			71.6		1					
	3.1.SM.1	7	33.3	68.7	80.0	75.6	44.50	7	3.60	5.90	5.11	0.82	6
	3.1.SM.1.SM	2	9.5	86.0	92.0	89.0	4.24	2			6.20		1
	3.1.SM.1.SM.SM	1	4.8			90.0		1					
	4.1.SM.1	9	42.9	63.0	81.1	72.5	63.51	9	2.50	5.47	4.12	1.04	7
	4.1.SM.1.SM.SM	1	4.8			72.0		1			3.70		1
Virgin large salmon	3.2	2	66.7	75.0	75.5	75.3	3.53	2			4.65		1
	4.2	1	33.3			76.0		1			4.90		1

Table 7. Food items found in stomachs of Atlantic cod and rock cod sampled in Gander Bay, 1998.

Prey item	Total number	Frequency of occurrence	Percent occurrence
Atlantic cod (Gadus morhua)			
Herring	*	68	54.4
Flat fish	*	12	9.6
Smolt	7	2	1.6
Sandlance	*	4	3.2
Lobster	*	1	0.8
Polychaetes	*	1	0.8
Shrimp	*	2	1.6
Smelt	*	1	0.8
American shad	*	1	0.8
stomach everted		1	0.8
stomach empty		6	4.8
unknown contents		16	12.8
Rock cod (Gadus ogac)			
Herring	*	4	50.0
stomach empty		4	50.0

* not available

Note: 125 Atlantic cod and 8 Rock cod were sampled

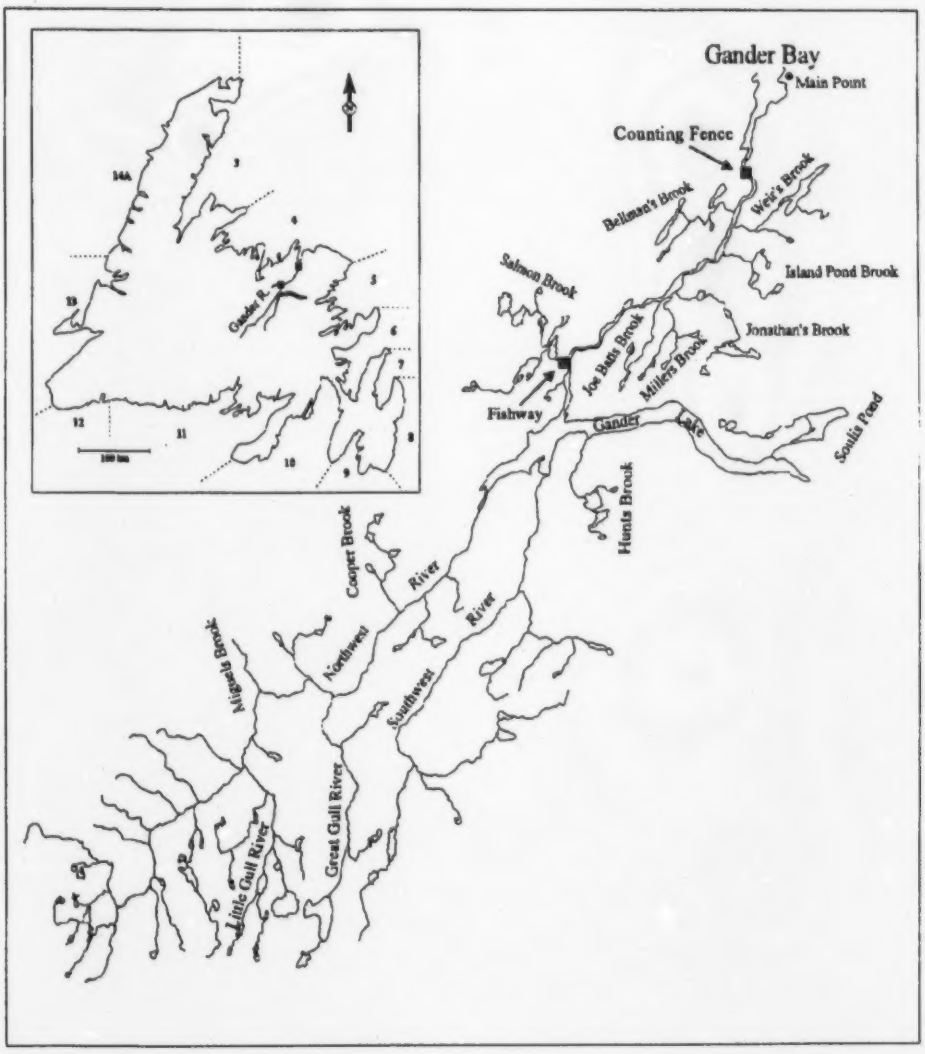

Fig. 1. Map showing the Gander River watershed and location of the counting fence in the lower river, the fishway in Salmon Brook, and the community of Main Point. Inset shows the Salmon Fishing Areas in Newfoundland and the location of Gander River.

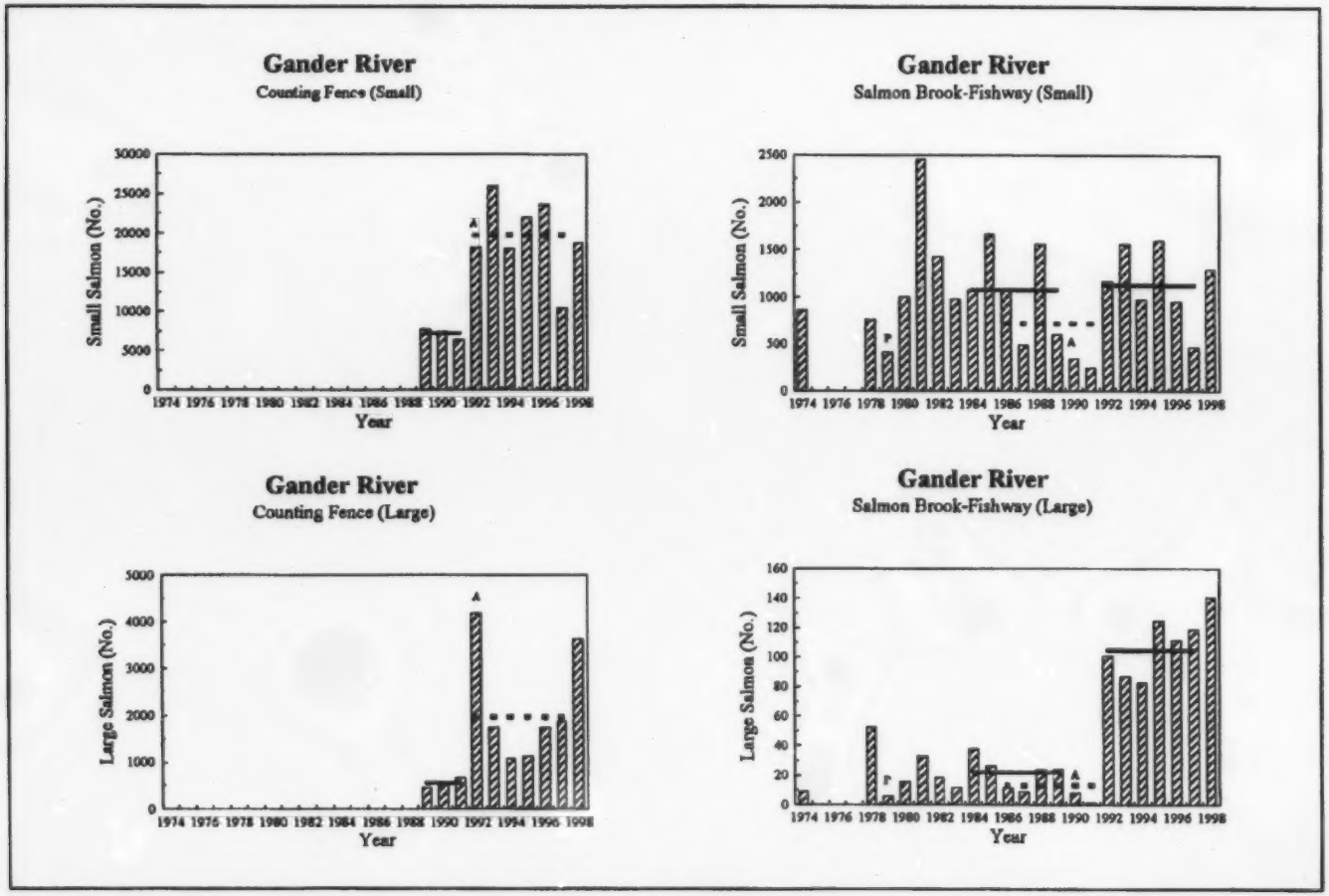

Fig. 2. Counts of small and large salmon at the Gander River counting fence and at the fishway located on the Salmon Brook tributary, 1974-198. The thin horizontal line represents the 1984-89 mean, the broken line the 1986-91 mean, and the thick solid line the 1992-97 mean. A = adjusted count; P = partial count, not included in the means.

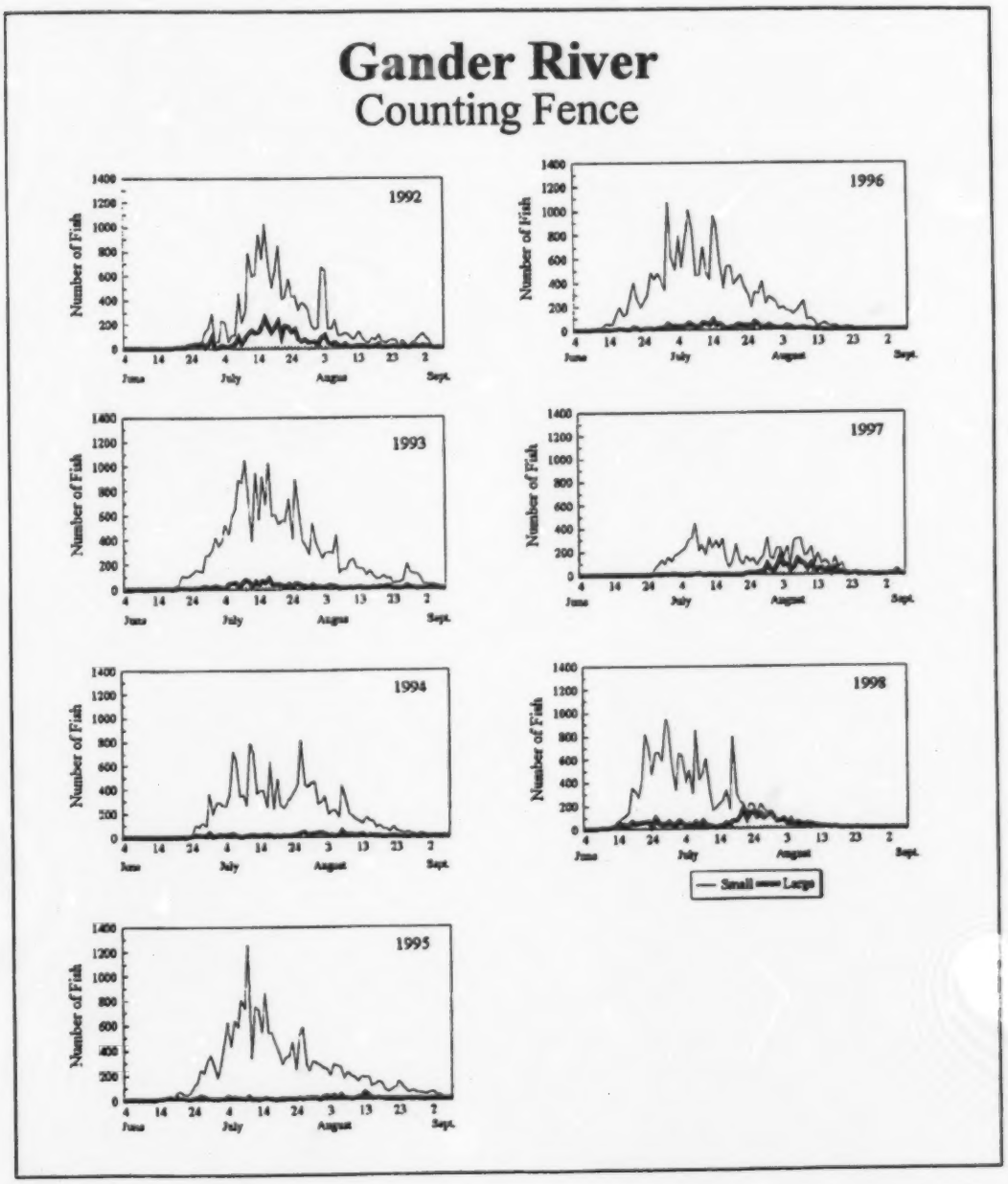

Fig. 3. Daily counts of small and large salmon at the Gander River counting fence, during the moratorium years, 1992-98.

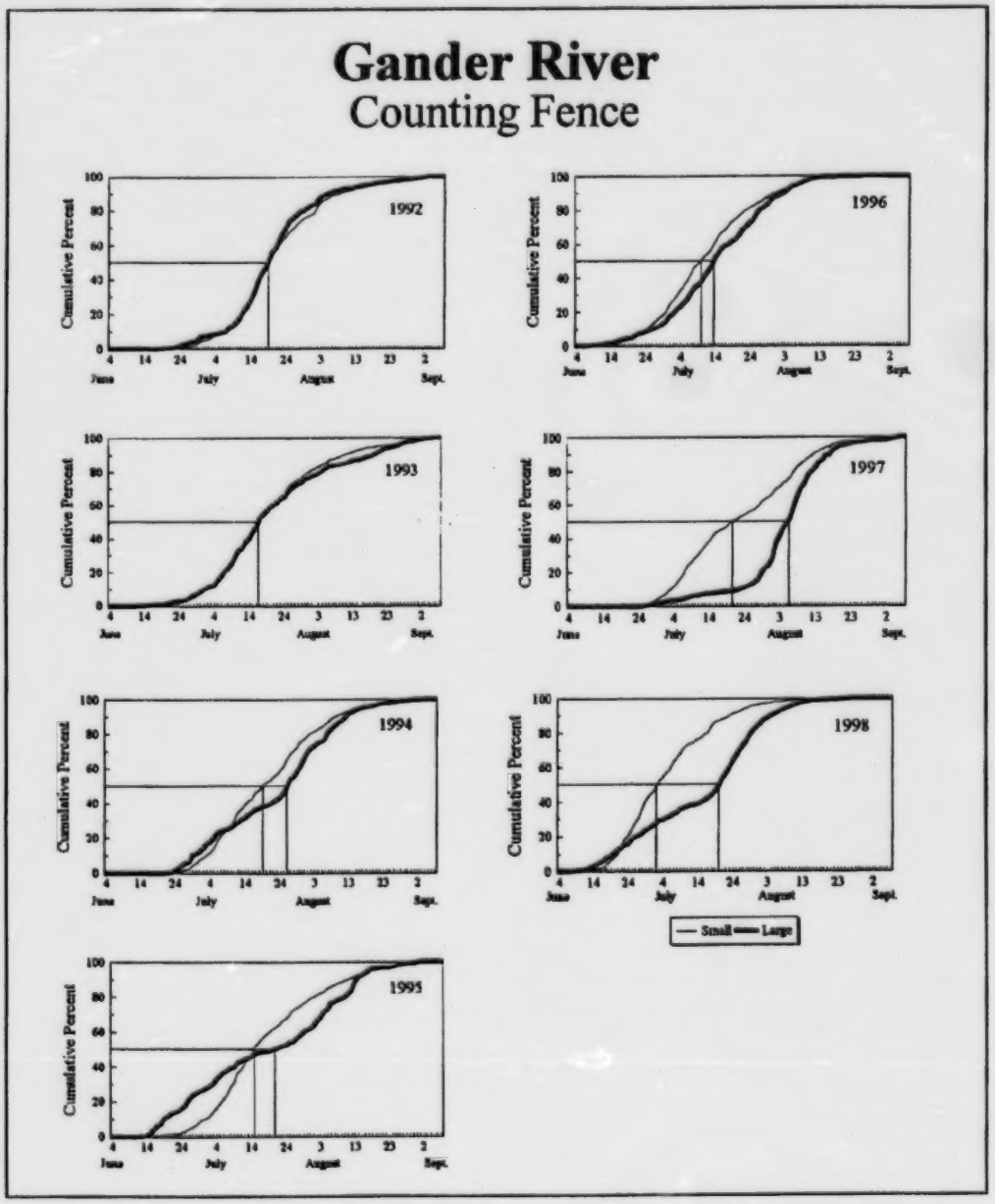

Fig. 4. Daily cumulative percent of small and large salmon at the Gander River counting fence, during the moratorium years, 1992-98. Dates of median counts are also shown.

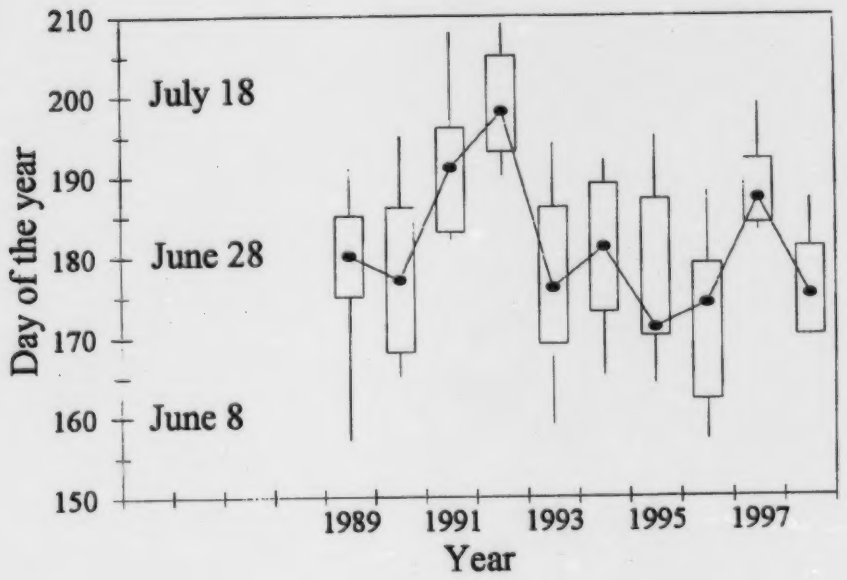

Fig. 5. Annual variation in smolt run timing for Gander River, 1989-98. Vertical lines represent the 10th and 90th percentiles, rectangles are the 25th and 75th percentiles, and the point within each rectangle is the median.

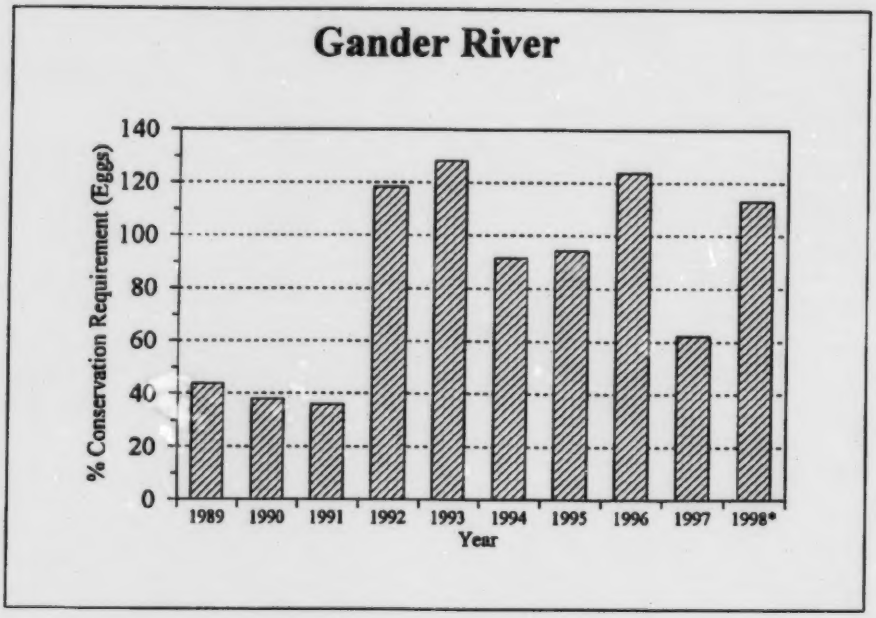

Fig. 6. Percentage conservation egg requirement achieved for Gander River, 1989-98. Asterisk denotes preliminary.

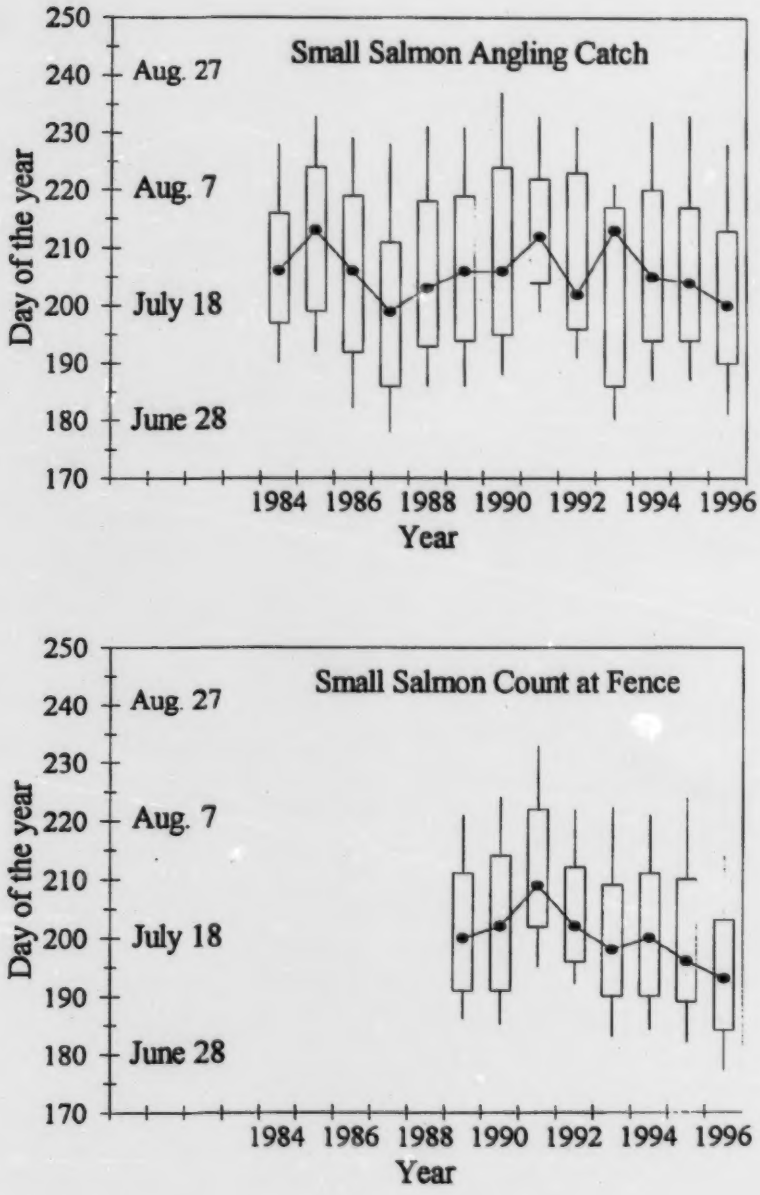

Fig. 7. Annual variation in timing of counts of small salmon and retained recreational catches of small salmon for Gander River, 1984-96. Vertical lines represent the 10th and 90th percentiles, rectangles are the 25th and 75th percentiles, and the point within each rectangle is the median. Catches in 1992 and 1993 were restricted by SFA quotas (see text).

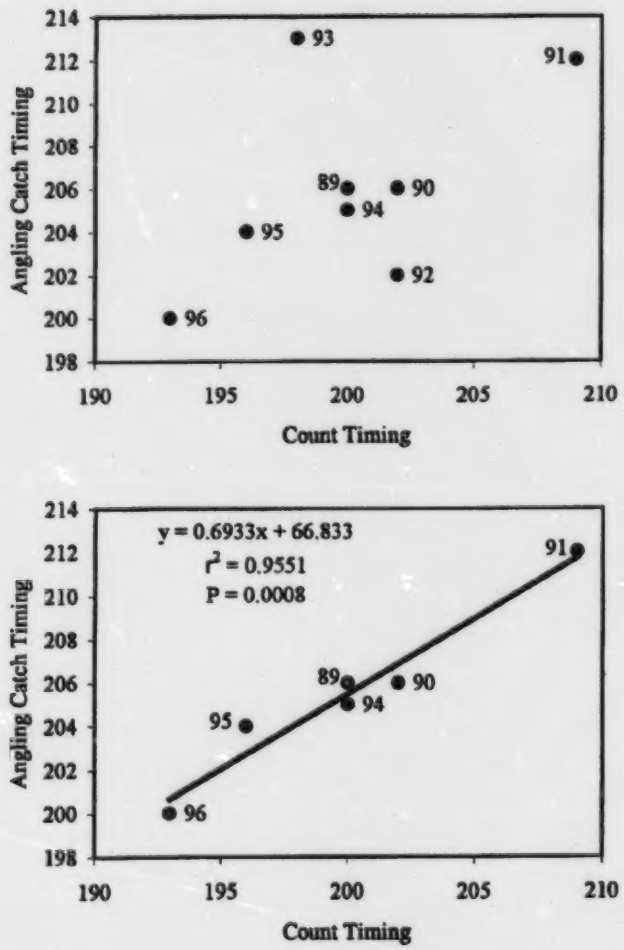

Fig. 8. The relationship between timing of retained recreational catches of small salmon and timing of small salmon counts through the counting fence. The years 1992 and 1993 have been omitted from the regression (see text).

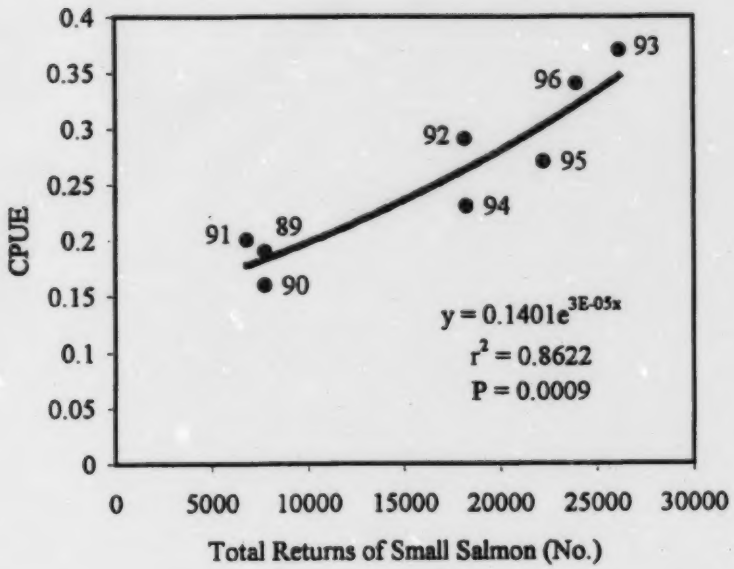

Fig. 9. Relationship between catch per unit of effort (CPUE) in the recreational fishery and total returns of small salmon, 1989-96.

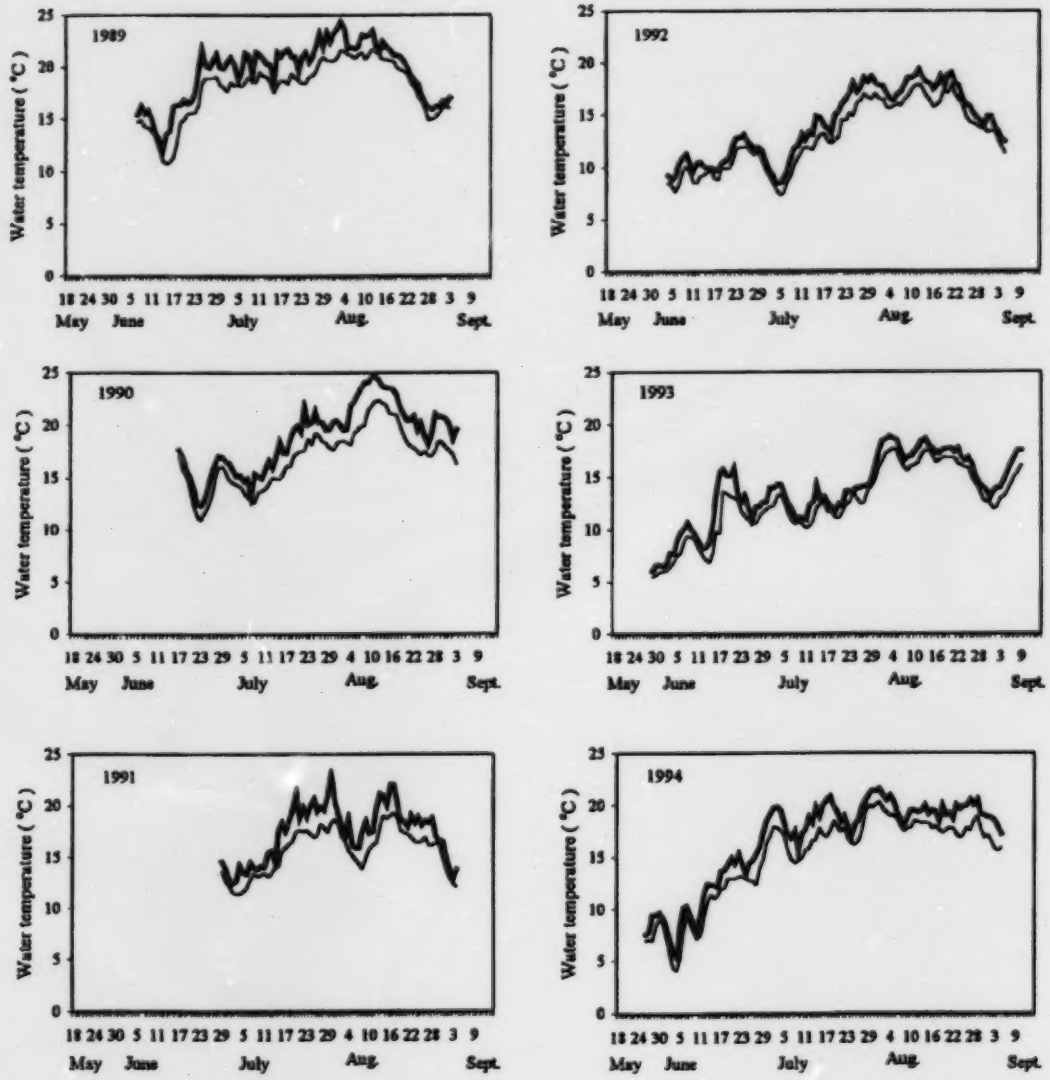

Fig. 10. Daily maximum and minimum water temperatures (°C) for Gander River, measured at the counting fence, 1989-98.

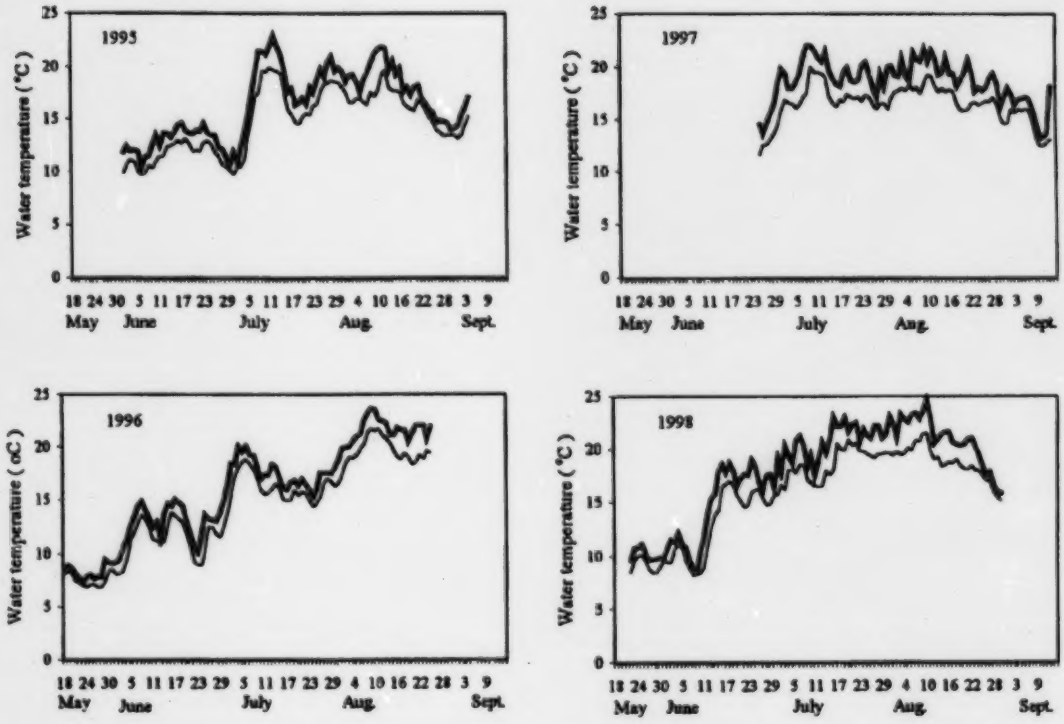
1995
1997
1996
1998
Water temperature (°C)
Water temperature (oC)
0
5
10
15
20
25
18 24 30 5 11 17 23 29 5 11 17 23 29 4 10 16 22 28 3 9
May June July Aug. Sept.

Fig. 10 (cont'd)

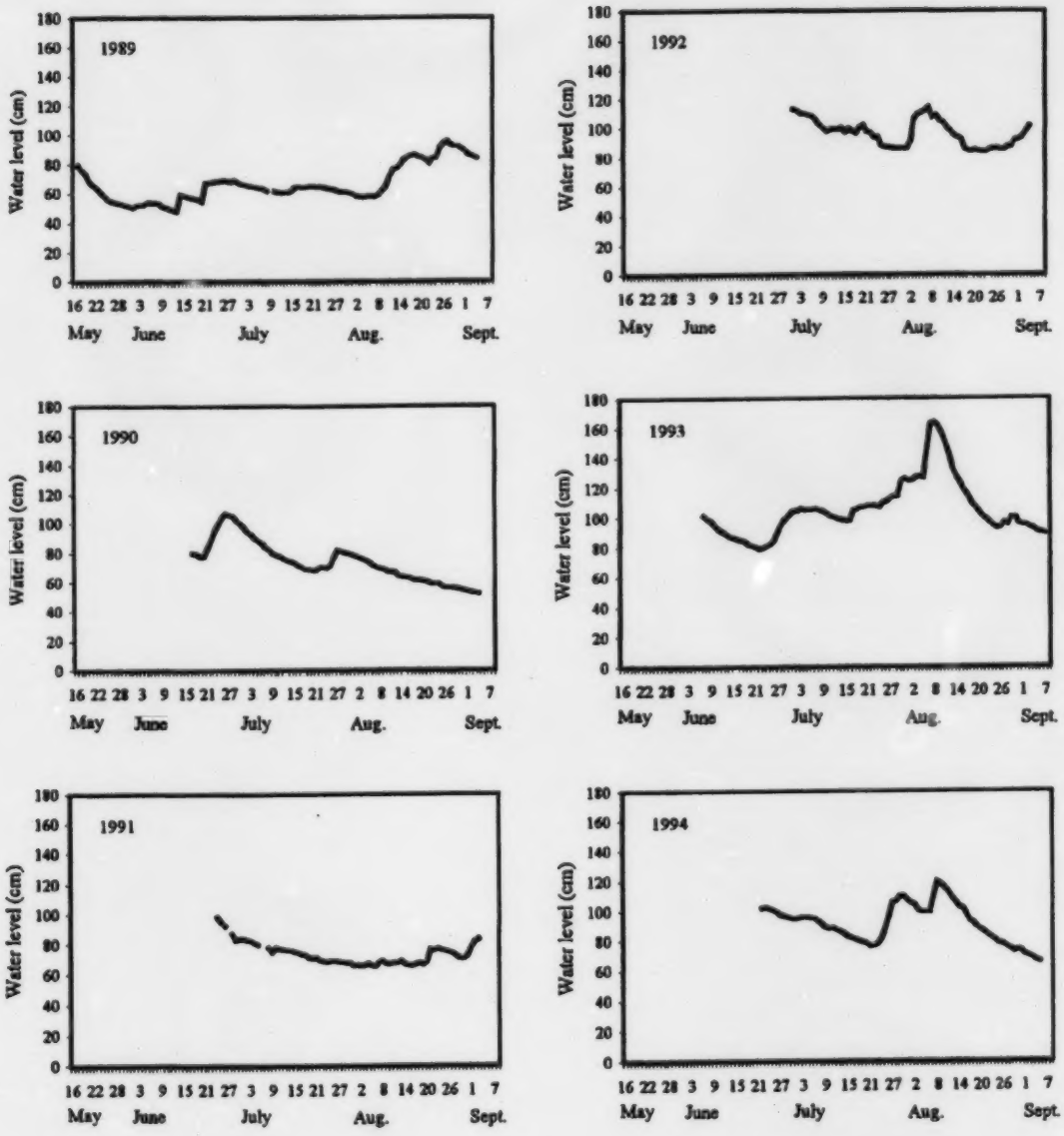

Fig. 11. Mean daily water levels (cm) for Gander River, measured near the counting fence, 1989-98.

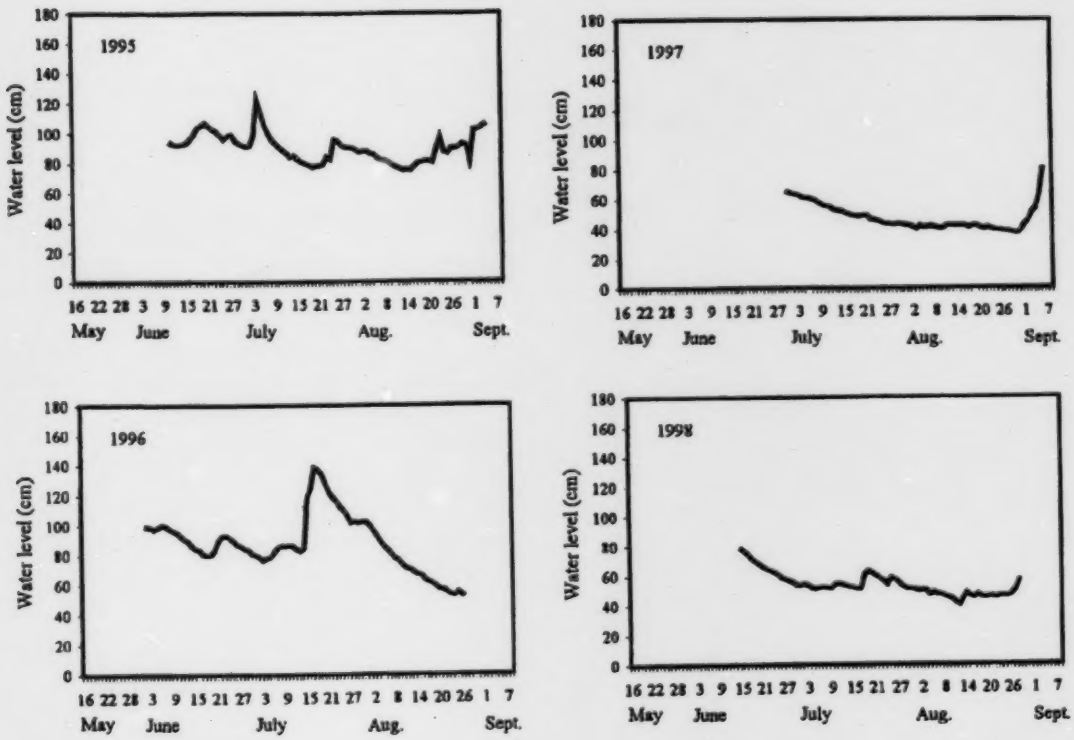
1995
1997
1996
1998
Water level (cm)
0 20 40 60 80 100 120 140 160 180
16 22 28 3 9 15 21 27 3 9 15 21 27 2 8 14 20 26 1 7
May June July Aug. Sept.

Fig. 11 (cont'd)

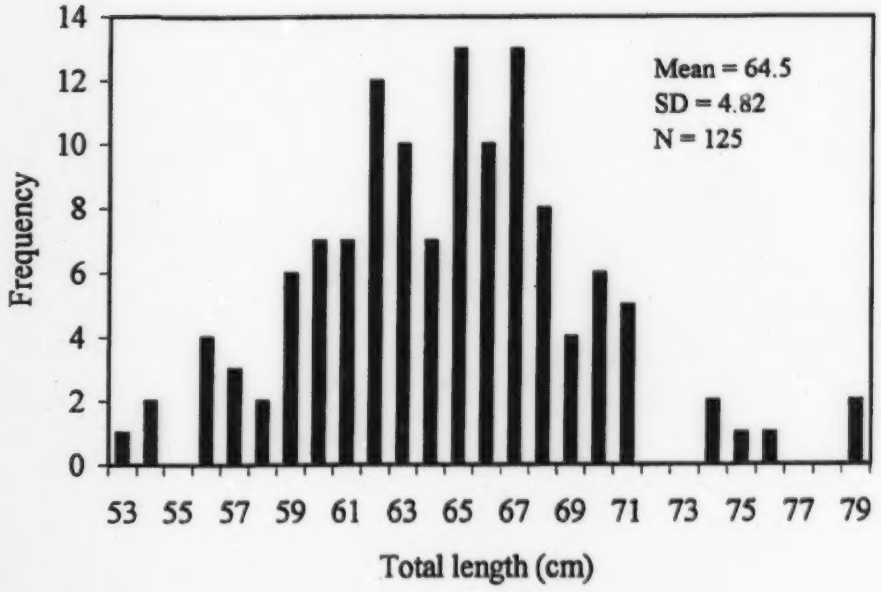

Fig. 12. Length frequency distribution of Atlantic cod caught in Gander Bay, 1998.

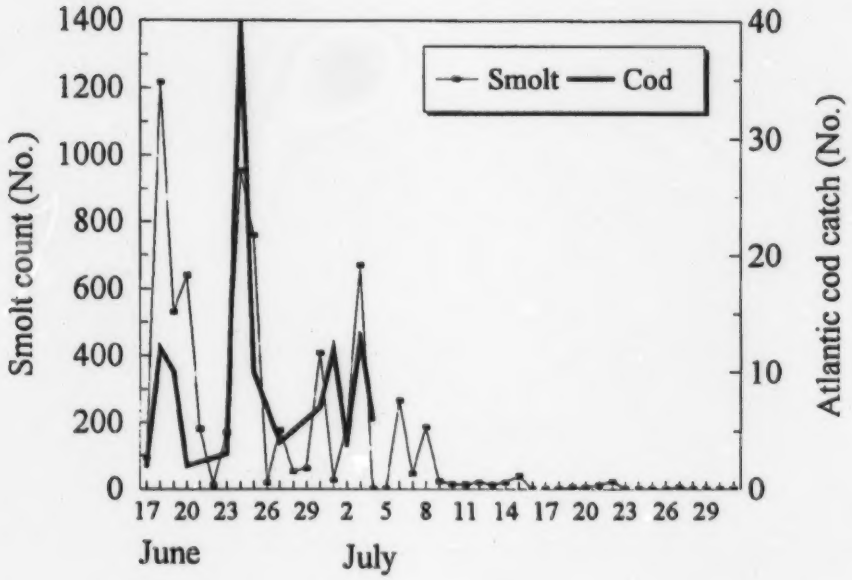

Fig. 13. Daily counts of smolts through the counting fence and daily catches of Atlantic cod in Gander Bay, 1998.

Appendix 1. Atlantic salmon recreational fishery catch and effort data for Gander River, Notre Dame Bay (SFA 4), 1974-98. Ret. = retained fish; Rel. = released fish.

	Effort	Small (<63 cm)			Large (>=63 cm)			Total (Small + Large)			
Year	Rod Days	Ret.	Rel.	Tot.	Ret.	Rel.	Tot.	Ret.	Rel.	Tot.	CPUE
1974	5153	2270	.	2270	19	.	19	2289	.	2289	0.44
1975	6670	2976	.	2976	38	.	38	3014	.	3014	0.45
1976	6633	2374	.	2374	132	.	132	2506	.	2506	0.38
1977	6939	2269	.	2269	927	.	927	3196	.	3196	0.46
1978	8322	3332	.	3332	389	.	389	3721	.	3721	0.45
1979	7217	4199	.	4199	318	.	318	4517	.	4517	0.63
1980	6384	2664	.	2664	268	.	268	2932	.	2932	0.46
1981	10643	4578	.	4578	249	.	249	4827	.	4827	0.45
1982	8026	2176	.	2176	205	.	205	2381	.	2381	0.30
1983	6934	2033	.	2033	239	.	239	2272	.	2272	0.33
1984	7590	2028	.	2028	13	.	13	2041	.	2041	0.27
1985	10207	3358	.	3358	*	.	0	3358	.	3358	0.33
1986	9740	2361	.	2361	*	.	0	2361	.	2361	0.24
1987	6384	1444	.	1444	*	.	0	1444	.	1444	0.23
1988	7943	2686	.	2686	*	.	0	2686	.	2686	0.34
1989	6290	1173	.	1173	*	.	0	1173	.	1173	0.19
1990	7118	1155	.	1155	*	.	0	1155	.	1155	0.16
1991	5853	1180	.	1180	*	.	0	1180	.	1180	0.20
1992	6273	1268	525	1793	*	3	3	1268	528	1796	0.29
1993	9073	1271	1950	3221	*	92	92	1271	2042	3313	0.37
1994	11287	2122	448	2570	*	39	39	2122	487	2609	0.23
1995	12215	2598	612	3210	*	74	74	2598	686	3284	0.27
1996	12347	2974	1153	4127	*	73	73	2974	1226	4200	0.34
1997**		1061	1007	2068	*	189***	189	1061	1196	2257	
1998**		1909	1652	3561	*	214	214	1909	1866	3775	
84-89 $\bar{X}$	8354.0	2321.2	.	2321.2	.	.	.	2323.8	.	2323.8	0.28
95% CL	1998.7	1003.6	.	1003.6	.	.	.	1002.1	.	1002.1	0.07
N	5	5	0	5	0	0	0	5	0	5	5
86-91 $\bar{X}$	7388.8	1711.0	.	1711.0	.	.	.	1711.0	.	1711.0	0.23
95% CL	1910.7	931.9	.	931.9	.	.	.	931.9	.	931.9	0.09
N	5	5	0	5	0	0	0	5	0	5	5
92-96 $\bar{X}$	10239.0	2046.6	937.6	2984.2	.	56.2	56.2	2046.6	993.8	3040.4	0.30
95% CL	3197.5	957.1	782.1	1075.8	.	43.9	43.9	957.1	814.4	1112.6	0.07
N	5	5	5	5	0	5	5	5	5	5	5

1987 DATA NOT INCLUDED IN MEAN.

IN THE ABOVE TABLE A PERIOD INDICATES NO DATA FOR THAT YEAR.

CPUE IS BASED ON RETAINED + RELEASED FISH FOR 1992 - 1996 AND ON RETAINED FISH ONLY PRIOR TO 1992.

* NOT ALLOWED TO RETAIN LARGE SALMON IN INSULAR NEWFOUNDLAND.

**DATA WERE OBTAINED FROM THE LICENSE STUB RETURN (1998 DATA ARE PRELIMINARY)

***PARTIAL

Appendix 2a. Maximum and minumim water temperatures (°C) measured at the counting fence in Gander River for the month of May, 1989-98.

Year		Date													
		18	19	20	21	22	23	24	25	26	27	28	29	30	31
1989	Max.														
	Min.														
1990	Max.														
	Min.														
1991	Max.														
	Min.														
1992	Max.														
	Min.														
1993	Max.												6.0	6.6	6.6
	Min.												5.4	5.6	5.9
1994	Max.									7.5	7.7	9.4	9.4	9.6	9.1
	Min.									6.9	7.1	6.9	8.3	9.1	8.6
1995	Max.														
	Min.														
1996	Max.	8.7	8.9	8.6	8.1	7.7	7.3	7.8	8.0	7.6	7.8	7.8	9.4	9.1	9.0
	Min.	8.1	8.4	8.1	7.4	7.2	6.9	6.8	7.1	7.1	6.8	6.8	7.3	8.3	8.5
1997	Max.														
	Min.														
1998	Max.					9.6	10.7	10.8	11.1	10.3	9.6	9.7	9.7	9.9	9.9
	Min.					8.4	9.6	10.1	10.1	9.6	8.8	8.4	8.4	9.0	9.6

Appendix 2b. Maximum and minimum water temperatures (°C) measured at the Gander River counting fence for the month of June, 1989-98.

Year		Date																												
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1989	Max.							15.4	16.2	15.5	15.8	14.9	13.4	13.1	12.0	13.5	13.8	16.2	16.3	16.3	16.8	16.4	16.7	17.4	19.7	21.6	20.1	19.9	20.6	21.2	19.9
	Min.							14.7	14.9	14.2	14.2	13.8	13.2	12.1	11.0	10.7	10.8	11.4	12.8	14.7	14.9	15.5	15.6	15.6	16.2	18.4	18.9	18.9	18.9	19.1	18.3
1990	Max.																	17.6	16.9	15.6	15.1	13.9	12.5	12.3	12.8	13.9	15.3	16.3	17.0	16.9	16.5
	Min.																	17.1	15.7	15.1	14.0	12.3	11.3	10.9	11.6	12.1	13.1	14.8	15.9	16.0	15.4
1991	Max.																													14.5	13.9
	Min.																													13.6	12.6
1992	Max.				9.2	8.8	9.1	10.3	10.9	11.3	10.3	9.6	10.4	10.5	10.1	9.9	10.0	9.6	9.8	10.4	10.6	10.9	12.1	12.8	12.8	13.1	12.5	12.1	11.7	11.9	11.6
	Min.				8.5	8.1	7.6	8.3	9.6	10.1	9.6	8.5	8.5	9.1	9.2	9.6	9.6	8.9	8.8	9.8	9.9	9.9	10.6	11.8	11.9	11.9	12.0	11.5	11.2	11.6	10.7
1993	Max.	6.4	6.8	7.7	7.7	8.9	9.7	10.1	10.6	9.9	9.6	8.9	8.1	8.2	8.7	10.5	13.3	15.4	15.7	15.1	15.1	15.8	13.4	12.6	13.2	12.0	10.9	12.1	12.1	12.6	12.6
	Min.	6.0	6.0	6.4	6.9	7.4	7.8	8.9	9.4	9.3	9.0	8.2	7.6	7.1	6.8	7.7	9.8	9.6	13.6	13.4	13.1	13.0	12.8	11.7	11.3	10.9	10.6	10.5	11.2	11.6	11.9
1994	Max.	8.4	7.1	5.7	5.3	8.1	10.1	10.3	9.4	8.5	7.9	9.4	11.4	12.4	12.3	12.3	12.1	13.6	13.7	14.3	14.9	14.4	15.3	14.4	13.4	14.4	14.6	15.3	15.9	17.4	18.5
	Min.	7.3	5.8	4.4	4.0	5.1	7.8	9.4	8.6	7.7	7.1	7.4	8.9	10.6	11.4	10.9	11.3	11.9	12.0	12.9	12.9	12.9	13.1	13.2	12.9	12.7	12.7	12.3	13.8	14.7	16.4
1995	Max.	11.8	12.4	11.9	12.0	11.9	10.4	11.3	11.4	12.6	13.4	12.4	13.6	13.6	13.2	13.7	14.4	14.6	13.9	13.6	13.5	13.9	13.8	14.5	13.6	13.4	13.4	12.2	12.1	11.2	10.5
	Min.	9.8	10.6	11.1	10.9	9.9	9.7	9.8	10.5	10.3	10.9	11.4	11.4	12.3	12.4	12.6	12.9	12.6	13.1	12.6	11.9	12.0	11.9	12.7	12.9	12.5	11.8	11.4	10.6	10.4	10.1
1996	Max.	9.1	9.4	10.5	11.2	12.6	13.4	14.4	14.8	13.9	13.4	12.4	12.9	11.4	13.7	14.6	14.4	15.0	14.7	14.4	13.1	11.8	10.6	10.1	11.8	13.6	13.2	13.1	13.0	13.8	14.9
	Min.	8.0	8.1	8.3	9.4	11.2	11.9	12.9	13.6	13.1	12.4	11.3	11.2	10.9	11.1	12.6	13.8	13.5	13.2	12.9	11.8	10.8	9.1	8.9	8.9	10.3	12.5	12.4	11.8	11.5	12.4
1997	Max.																									14.5	13.6	14.6	15.5	16.4	18.3
	Min.																									11.6	12.5	12.6	13.1	13.6	14.4
1998	Max.	10.8	11.5	11.3	12.1	11.1	10.8	9.5	8.8	8.7	10.4	11.8	13.9	15.3	15.7	17.9	18.5	17.8	18.7	18.0	16.5	17.2	17.6	17.5	18.9	18.4	16.9	16.1	17.5	17.6	16.3
	Min.	9.4	9.4	10.6	11.1	10.7	9.6	8.8	8.2	8.3	8.4	8.9	11.0	12.7	13.8	14.3	16.4	16.7	17.0	16.6	15.6	15.1	14.5	14.7	15.9	16.1	16.2	15.3	14.7	14.8	15.6

Appendix 2c. Maximum and minimum water temperatures (°C) measured at the Gander River counting fence for the month of July, 1989-98.

Year		Date																													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1989	Max.	19.8	20.5	20.9	20.2	18.8	19.5	21.3	21.1	19.1	21.4	21.2	20.8	20.3	20.2	18.6	21.4	21.0	21.5	21.7	21.0	21.0	19.5	20.9	21.4	20.5	21.0	22.1	23.2	21.9	23.3	22.4
	Min.	18.0	17.6	18.5	18.2	18.3	18.1	18.5	19.0	18.7	18.5	19.5	19.2	19.1	18.5	17.5	18.2	18.7	18.7	18.3	19.4	18.9	18.7	18.4	18.4	19.0	19.2	19.6	20.5	21.0	20.6	20.6
1990	Max.	16.3	15.6	15.1	15.2	14.6	14.9	13.1	15.3	15.1	14.9	15.8	16.6	15.9	16.9	18.4	17.3	17.3	18.7	19.6	19.9	19.3	21.7	20.0	20.2	21.3	20.2	20.2	19.5	19.6	20.3	20.4
	Min.	14.7	14.4	14.3	14.1	13.6	13.1	12.8	12.6	13.6	13.7	13.9	14.4	15.0	14.9	14.8	15.4	16.1	16.0	17.1	17.3	17.5	17.5	18.7	18.1	19.2	19.0	18.4	18.3	17.8	17.6	18.1
1991	Max.	12.8	12.4	12.6	14.1	13.4	13.3	14.4	14.0	13.8	14.1	14.0	15.4	15.6	14.5	17.6	18.3	17.5	18.5	19.5	21.3	18.7	19.8	18.9	19.9	20.6	19.4	19.9	19.6	21.0	22.9	20.4
	Min.	12.3	11.5	11.4	11.4	11.6	11.9	12.8	13.4	13.1	13.2	13.4	13.1	13.3	14.1	14.1	15.6	15.9	16.3	16.5	17.5	17.6	17.5	17.6	17.3	16.9	17.0	18.2	17.8	17.4	18.3	18.6
1992	Max.	10.6	9.7	9.2	8.4	8.4	8.9	9.6	11.0	11.8	12.0	13.1	12.6	13.3	13.1	14.8	14.7	14.0	13.6	13.1	14.9	15.3	16.0	16.4	17.0	18.0	17.1	17.6	18.5	18.1	18.6	18.0
	Min.	9.7	9.2	8.5	7.8	7.3	7.5	8.6	9.2	10.2	10.9	11.6	11.9	11.8	11.6	12.4	13.1	13.2	12.4	12.2	12.6	12.9	14.5	14.4	15.1	14.8	16.1	16.3	16.9	16.6	16.4	17.0
1993	Max.	13.9	13.9	14.3	14.3	13.3	12.4	11.9	11.1	11.1	11.1	10.9	12.3	12.6	14.1	12.7	13.1	12.5	12.0	11.7	12.4	12.2	13.6	13.6	13.6	13.9	13.9	14.1	14.1	14.6	15.8	17.3
	Min.	12.1	12.2	13.1	13.4	12.5	11.5	10.9	10.4	10.8	10.4	10.1	10.3	10.9	12.0	12.4	12.4	11.6	11.6	11.1	11.1	11.6	12.3	12.6	13.4	12.9	12.4	12.5	13.7	14.0	14.7	15.8
1994	Max.	19.1	19.7	19.8	19.5	18.3	17.1	16.8	17.5	15.6	17.3	17.6	18.8	18.3	19.8	18.9	20.0	20.5	20.8	19.8	19.4	18.4	18.9	17.9	16.9	18.0	18.6	19.8	20.5	21.0	21.4	21.3
	Min.	17.0	17.9	17.8	17.6	17.0	15.6	14.8	14.4	14.6	14.9	15.6	15.8	16.6	16.6	17.8	17.1	16.9	17.5	18.5	17.9	17.4	17.9	16.8	16.3	16.2	16.6	17.5	19.4	20.0	19.7	20.0
1995	Max.	11.8	10.8	12.1	13.6	15.4	17.5	19.2	21.4	21.4	21.1	21.9	22.9	21.9	21.0	19.7	17.5	17.9	16.3	16.5	17.0	16.4	18.0	17.5	18.7	19.8	19.0	20.4	20.9	19.5	19.9	19.5
	Min.	9.7	10.4	10.4	11.1	13.4	15.1	17.1	17.4	19.5	19.4	19.9	19.6	19.5	19.3	17.6	15.9	15.3	14.7	14.5	15.1	15.5	15.3	16.2	16.4	17.5	18.3	18.4	18.6	18.5	18.5	18.0
1996	Max.	16.4	18.4	18.3	20.0	19.5	20.0	19.2	19.2	17.9	16.9	17.3	17.3	18.3	18.0	16.9	16.0	15.9	16.6	16.8	16.3	16.9	16.4	15.9	15.3	15.9	17.5	17.5	17.5	17.4	18.0	18.8
	Min.	13.8	15.4	17.1	18.0	18.5	18.8	18.3	17.8	16.9	15.9	15.5	15.6	16.0	16.5	16.0	14.9	14.9	14.9	15.9	15.4	15.7	15.6	14.9	14.3	14.6	15.2	16.5	17.0	16.6	16.2	16.6
1997	Max.	19.8	19.3	17.9	17.9	18.5	19.3	20.9	22.0	22.0	21.5	20.9	20.5	21.4	19.6	18.9	18.3	18.1	19.5	19.9	18.6	18.5	18.7	20.1	20.4	19.2	17.9	17.1	19.3	18.1	20.0	20.1
	Min.	15.8	16.8	16.5	16.5	16.0	16.3	17.0	17.5	20.0	19.4	19.5	19.3	19.0	17.1	16.5	16.1	16.8	16.6	17.4	17.0	16.9	17.1	16.6	17.3	17.0	16.3	15.9	16.5	16.5	15.9	16.9
1998	Max.	19.1	17.8	20.3	19.3	18.6	20.8	21.2	20.3	18.4	19.4	17.5	18.9	20.6	19.6	20.9	22.9	22.1	22.1	22.9	21.6	22.3	22.5	20.7	21.8	21.3	21.0	22.2	22.2	21.0	21.3	23.0
	Min.	15.7	16.6	16.1	18.0	18.0	17.7	18.5	18.5	17.0	16.8	16.5	16.5	16.5	17.9	17.5	18.0	20.5	20.0	19.9	20.9	20.3	20.5	19.8	19.8	19.5	19.3	19.1	19.5	19.5	19.6	19.6

Appendix 2d. Maximum and minimum water temperatures (°C) measured at the Gander River counting fence for the month of August, 1989-98.

Year		Date																													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1989	Max.	23.3	23.7	24.3	23.7	21.8	21.9	21.7	22.0	23.1	22.9	23.1	23.5	22.1	21.3	22.4	21.9	21.6	21.1	21.1	21.0	20.5	19.8	19.1	18.6	18.3	17.1	16.5	16.0	15.9	16.2	16.2
	Min.	20.6	20.9	21.6	21.5	21.2	21.1	20.8	21.2	21.4	20.7	21.2	21.7	21.4	21.2	20.7	20.7	20.6	20.6	19.9	19.7	19.6	19.3	18.4	18.0	17.1	16.7	15.8	14.9	15.0	15.2	15.6
1990	Max.	20.0	19.5	19.6	21.9	22.1	22.9	23.5	24.0	24.0	24.6	24.6	24.2	23.7	23.5	23.5	23.4	22.9	21.7	21.0	20.4	20.4	20.8	19.4	20.1	18.8	18.1	19.0	21.0	20.7	20.7	20.5
	Min.	18.5	18.5	18.3	18.1	19.1	19.5	19.9	19.9	21.4	21.8	22.2	22.3	22.1	21.9	21.1	21.0	20.9	20.0	19.1	18.3	17.9	17.8	17.4	17.1	17.5	17.0	17.0	17.5	18.5	18.2	17.8
1991	Max.	19.1	18.0	17.0	18.6	16.1	15.9	15.9	17.5	18.4	17.3	17.5	19.8	21.1	20.9	20.1	22.0	22.0	20.1	18.6	18.4	17.9	19.0	18.3	18.9	18.1	18.5	18.3	18.7	17.0	16.6	16.5
	Min.	18.2	17.0	16.5	15.7	15.1	14.8	14.3	13.8	14.9	15.8	16.1	16.4	17.9	19.0	18.7	19.0	19.3	18.8	17.6	17.4	17.2	16.9	16.5	16.4	16.5	16.9	16.1	16.1	16.4	16.3	14.9
1992	Max.	17.8	17.7	17.0	16.5	16.3	16.9	17.1	17.8	18.5	18.5	18.7	19.3	18.5	18.1	18.0	17.4	17.8	18.7	17.8	18.8	19.0	17.9	17.8	16.6	15.9	15.8	15.1	14.7	14.4	13.9	14.8
	Min.	16.5	16.5	15.7	15.6	15.8	16.0	15.8	16.4	16.7	17.3	17.7	17.9	17.5	16.8	16.3	15.7	15.9	16.3	17.4	17.0	17.9	16.9	16.5	16.0	14.8	14.3	14.2	14.0	13.7	13.6	13.3
1993	Max.	18.4	18.5	18.8	18.6	18.5	17.4	16.5	16.8	16.9	17.3	17.8	18.4	18.6	17.9	17.7	17.2	17.2	17.6	17.6	17.7	17.3	17.7	16.8	16.5	16.8	16.2	14.9	14.4	13.9	13.7	12.9
	Min.	16.5	17.2	17.3	17.7	17.4	16.5	15.8	15.5	16.0	16.1	16.3	17.1	17.5	17.5	16.9	16.3	16.6	16.8	16.8	16.8	16.8	16.2	16.1	15.8	15.9	14.9	14.3	13.7	12.9	12.6	12.5
1994	Max.	21.6	20.9	20.5	20.9	20.4	19.2	18.6	18.0	18.8	19.5	19.5	19.3	19.5	20.0	19.1	19.5	19.4	18.5	19.9	19.0	19.2	18.6	20.0	19.6	19.9	19.9	20.5	20.0	20.5	19.1	19.0
	Min.	20.3	19.6	19.3	18.9	19.0	18.6	18.0	17.5	17.8	17.8	18.5	18.4	18.2	18.3	18.3	17.7	18.0	17.6	17.3	17.6	17.8	17.8	17.2	16.8	17.2	17.8	17.6	18.4	18.9	17.7	16.8
1995	Max.	18.5	19.1	19.2	18.5	17.5	18.8	19.3	20.3	21.2	21.6	21.8	21.7	19.6	20.5	19.2	19.8	17.5	18.0	17.2	18.0	18.2	16.9	16.5	15.8	15.6	14.6	14.8	14.7	14.6	13.9	14.1
	Min.	17.4	16.5	16.5	16.9	16.9	16.5	16.3	17.5	17.0	17.7	19.2	19.6	17.9	17.6	17.6	17.5	16.5	16.1	15.9	15.7	16.8	16.4	15.9	15.1	14.7	13.9	13.7	13.3	13.4	13.4	13.4
1996	Max.	19.8	19.9	20.0	20.5	21.0	21.2	22.5	23.2	23.6	23.5	22.5	22.4	22.2	21.1	21.1	21.8	21.6	21.6	20.4	21.3	22.0	22.0	22.0	20.7	21.9						
	Min.	17.3	18.4	19.0	18.9	19.2	19.8	20.2	21.4	21.7	21.5	21.7	21.1	20.7	20.3	19.6	19.0	18.8	19.4	19.0	18.3	18.5	19.2	18.8	19.6	19.4						
1997	Max.	19.1	19.0	20.7	19.0	18.6	21.3	20.7	20.5	21.7	20.5	21.5	20.8	19.2	19.5	20.8	19.3	19.3	18.1	18.7	19.4	20.6	19.5	17.6	18.0	17.7	18.0	18.9	19.3	18.4	16.1	17.0
	Min.	17.6	17.7	17.9	17.7	18.2	17.7	18.1	17.4	18.4	19.2	19.1	18.1	17.6	17.9	17.6	17.8	17.6	16.4	15.8	15.8	15.9	16.5	16.6	16.3	16.5	16.7	16.6	17.1	16.3	15.1	14.5
1998	Max.	22.4	21.1	23.3	22.8	22.5	23.3	23.4	22.8	23.5	24.6	23.0	20.5	20.9	21.4	21.6	21.6	20.6	20.4	20.3	20.4	20.9	21.0	20.2	19.5	18.4	17.5	17.8	16.6	15.9	15.8	
	Min.	19.3	19.8	19.4	19.5	20.1	19.9	20.8	20.7	21.4	21.5	19.8	19.0	19.2	18.3	18.5	18.7	18.6	19.0	18.4	18.1	18.0	18.4	17.9	18.0	17.5	17.0	16.9	15.9	15.4	15.1	

Appendix 2e. Maximum and minumim water temperatures (°C) measured at the counting fence in Gander River for the month of September, 1989-98.

Year		Date												
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1989	Max.	16.7	16.5	17.0											
	Min.	16.1	16.1	16.0											
1990	Max.	20.0	18.6	19.5											
	Min.	17.5	17.1	16.2											
1991	Max.	14.9	13.6	12.9	13.8										
	Min.	13.6	13.0	12.3	12.1										
1992	Max.	14.8	13.8	13.4	12.6	12.4									
	Min.	13.4	13.5	12.6	11.9	11.3									
1993	Max.	13.6	13.9	13.9	14.7	15.4	16.2	16.8	17.5	17.5					
	Min.	11.9	12.1	12.9	13.1	13.6	14.3	15.0	15.4	16.1					
1994	Max.	18.8	18.8	18.5	17.9	17.2									
	Min.	17.1	16.6	15.8	15.6	15.9									
1995	Max.	14.3	15.3	16.0	17.0										
	Min.	13.1	13.4	14.4	15.2										
1996	Max.														
	Min.														
1997	Max.	18.0	17.4	16.3	16.8	16.9	17.0	16.9	15.9	14.8	13.1	13.3	13.6	18.1	
	Min.	14.6	15.9	15.6	15.9	15.8	15.9	15.9	14.8	13.1	12.4	12.4	12.7	13.1	
1998	Max.														
	Min.														

Appendix 3. Mean daily water levels (cm) measured near the counting fence in Gander River, 1989-98.

Month	Day	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
May	17	79.3									
	18	75.5									
	19	73.5									
	20	68.8									
	21	66.0									
	22	63.9									
	23	61.4									
	24	58.5									
	25	56.0									
	26	54.8									
	27	54.0									
	28	53.0									
	29	52.8									
	30	51.5									
	31	51.3									
June	1	50.3									
	2	51.5							99.0		
	3	52.0							98.4		
	4	52.0							97.0		
	5	53.8							98.6		
	6	54.0							100.0		
	7	53.5				101.2			99.6		
	8	53.5				98.8			97.4		
	9	50.8				97.4			96.5		
	10	50.3				94.5			95.0		
	11	49.5				92.0		93.5	92.6		
	12	48.5				90.5		92.0	90.6		
	13	47.8				89.0		92.0	89.0		
	14	59.0				87.4		92.7	86.3		
	15	58.5				86.7		93.3	84.2		78.0
	16	57.5				85.5		95.8	83.3		76.0
	17	56.7	79.5			84.8		99.0	80.5		73.5
	18	56.6	79.3			84.3		103.5	79.5		70.5
	19	55.8	77.4			81.7		105.0	80.0		69.0
	20	54.5	77.8			81.2		107.0	83.8		67.4
	21	67.0	82.8			80.5		104.8	89.2		66.0
	22	67.3	88.2			79.1	101.5	103.0	92.5		64.0
	23	67.8	95.2			79.8	102.3	101.2	93.0		63.1
	24	68.3	99.8	98.0		81.0	101.3	98.6	91.5		62.0
	25	68.3	103.8	94.5		82.2	100.6	96.0	89.0		60.5
	26	68.9	106.8	92.3		85.6	99.0	98.1	86.9		58.3
	27	68.3	105.8			91.5	96.8	98.8	86.0		57.5
	28	68.0	103.0	87.3		96.6	96.5	95.0	84.2		56.3
	29	69.0	101.4	83.0		99.3	95.6	93.4	83.1		55.3
	30	67.5	99.6	83.8		101.7	94.7	92.0	80.8	65.0	53.0
July	1	66.0	97.0	84.0	113.0	104.4	94.4	91.0	80.0	63.9	53.7
	2	66.0	94.0	83.0	112.3	104.4	95.0	91.3	78.7	62.9	54.7
	3	65.0	92.6	82.5	110.0	106.0	96.0	98.3	76.3	62.5	53.3
	4	65.0	90.0	81.0	110.0	105.2	95.8	122.3	78.0	61.0	51.2
	5	64.0	88.5	80.0	109.0	105.6	95.0	113.8	78.7	61.0	51.0
	6	63.7	86.3		108.6	105.3	95.0	106.2	82.0	60.0	52.0
	7	63.0	83.8		105.7	106.0	92.8	100.5	85.0	59.4	52.0
	8	62.0	82.0	78.0	102.0	105.0	91.0	95.8	86.1	57.5	51.6
	9		79.5	75.1	100.0	104.0	88.8	93.0	85.7	56.0	51.3
	10	61.5	78.3	78.0	98.0	102.7	88.0	90.5	86.2	55.0	53.7
	11	61.0	77.5	77.0	99.3	100.7	88.8	88.3	86.1	55.0	54.5
	12	60.0	76.0	76.3	99.0	100.0	87.4	86.4	83.6	53.0	54.0
	13	60.8	75.1	76.2	99.0	99.0	86.0	84.0	82.4	52.0	53.0
	14	61.0	74.0	76.0	100.0	98.2	84.8	85.3	84.3	52.0	52.0
	15	62.0	73.2	74.9	97.0	97.7	82.3	82.5	118.2	50.7	52.0

Appendix 3 (cont'd)

Month	Day	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
July	16	64.5	71.5	74.7	99.3	97.8	82.0	80.4	125.0	50.0	51.0
	17	64.7	70.4	73.0	98.0	104.4	81.0	79.6	138.0	49.0	51.0
	18	64.0	69.0	73.0	96.5	105.3	79.8	78.4	137.0	48.5	60.3
	19	64.5	68.8	71.0	100.7	106.8	79.0	77.0	134.2	48.0	63.0
	20	65.0	68.3	71.0	102.0	107.0	78.3	77.8	127.8	49.0	61.5
	21	65.0	68.0	71.4	97.0	108.0	76.0	78.0	122.0	48.7	59.7
	22	64.0	70.0	69.0	97.3	107.7	76.5	79.0	118.4	46.0	57.8
	23	64.8	70.2	68.7	93.7	108.0	78.0	84.0	115.9	46.0	56.5
	24	63.7	69.8	68.6	94.0	107.0	81.5	82.4	111.8	45.0	54.0
	25	63.0	71.3	69.3	88.0	110.0	87.8	95.3	109.2	44.0	58.3
	26	63.0	76.5	69.3	87.0	110.3	96.3	94.5	106.1	43.0	57.0
	27	62.1	81.8	68.5	87.0	112.7	105.6	91.6	101.3	43.0	54.8
	28	61.4	81.0	68.5	86.0	114.0	105.9	90.1	102.2	42.8	52.5
	29	61.0	79.8	67.7	86.0	114.5	109.6	90.0	101.2	43.0	51.0
	30	61.0	79.5	68.0	86.0	124.2	109.6	90.0	101.8	43.0	51.0
	31	60.0	78.8	66.0	86.0	125.6	106.9	88.3	102.0	42.0	50.6
August	1	59.3	77.7	66.1	86.0	124.3	104.9	87.0	99.7	42.1	49.5
	2	57.8	76.6	66.0	91.0	124.6	103.8	87.5	96.0	40.9	50.0
	3	57.4	75.8	66.0	106.0	127.0	100.0	87.5	92.5	40.0	49.7
	4	57.2	74.8	67.3	109.5	127.2	99.0	86.0	88.8	41.7	47.0
	5	58.0	73.3	66.0	110.7	126.6	99.0	85.4	85.7	40.5	48.3
	6	57.8	71.0	65.7	112.0	145.6	99.0	83.0	83.2	41.0	47.3
	7	57.7	69.8	68.3	114.0	162.5	109.8	81.6	80.3	41.5	47.0
	8	59.0	69.2	69.0	107.5	163.7	119.0	81.3	77.5	40.5	46.0
	9	61.8	68.8	67.0	109.0	161.3	118.0	80.0	76.2	40.1	45.0
	10	64.0	67.0	67.0	105.0	156.0	115.4	78.3	73.0	40.3	44.0
	11	70.8	67.0	67.7	104.0	149.3	112.6	77.3	70.8	42.0	42.0
	12	76.0	66.5	67.6	100.0	141.7	109.0	76.0	70.3	42.0	40.0
	13	77.2	64.2	69.0	98.0	132.8	105.7	74.8	68.9	42.0	44.0
	14	79.0	63.5	66.5	95.0	127.2	102.5	75.7	66.7	42.0	47.7
	15	82.8	63.3	66.3	93.5	123.2	101.5	75.0	66.6	42.0	46.0
	16	84.8	63.0	66.0	92.8	118.2	97.2	77.3	63.3	42.0	45.0
	17	85.5	61.6	67.2	86.0	114.8	93.2	80.0	62.0	41.0	46.8
	18	86.3	61.0	67.7	84.3	109.7	92.0	80.0	61.0	42.0	45.0
	19	85.0	61.0	66.5	84.0	107.3	89.3	81.0	58.6	42.0	45.0
	20	84.5	60.7	68.5	85.0	103.5	87.3	81.0	57.0	40.6	46.0
	21	83.2	60.0	76.8	84.0	100.2	85.6	80.0	57.0	40.0	45.5
	22	80.9	59.0	76.0	84.0	98.8	83.7	89.3	55.0	41.0	45.0
	23	84.0	58.4	77.0	83.7	96.8	82.0	96.7	53.4	40.0	46.3
	24	84.3	59.0	76.0	85.0	94.4	80.2	87.0	53.0	39.0	46.0
	25	91.2	56.6	75.8	86.3	92.7	78.4	86.0	54.9	39.3	46.0
	26	94.0	55.8	75.0	86.0	93.0	77.8	89.5	53.0	38.5	47.0
	27	95.7	55.8	74.0	85.0	96.5	76.0	89.0		38.5	50.3
	28	92.8	56.0	72.0	85.0	95.3	74.7	90.3		38.0	56.0
	29	92.0	55.3	70.5	86.8	99.8	73.0	92.3		37.4	
	30	91.9	55.0	70.8	87.3	100.0	74.0	91.8		37.0	
	31	90.3	54.0	72.4	91.7	95.5	73.4	81.2		38.7	
September	1	88.5	53.6	78.0	92.0	95.0	70.8	101.3		42.8	
	2	86.2	53.0	81.8	93.5	95.0	70.0	102.0		45.7	
	3	85.1	52.3	83.8	96.7	93.5	69.0	103.4		51.2	
	4	84.0	52.0		101.0	92.3	67.0	105.0		53.8	
	5					90.7	66.0			62.6	
	6					90.0				80.0	
	7					89.0					